REVISION 1
FINAL COMPLETION REPORT
CHARACTERIZATION WELL R-4
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
PROJECT NO. 37151/7.12

Prepared for:

The United States Department of Energy and the
National Nuclear Security Administration through the
United States Army Corps of Engineers
Sacramento District

Prepared by:

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LIST OF ACRONYMS AND ABBREVIATIONS

AITH	array induction tool, version H
ASTM	American Society for Testing and Materials
bgs	below ground surface (Page v in the Abstract)
°C	degrees Celsius
CD	compact disc
CMR	Combined Magnetic Resonance
CNTG	compensated neutron tool, model G
CQMP	Contractor Quality Management Plan
DH	down hole
DOE	United States Department of Energy
DP	Drilling Plan
DTH	down-the-hole
DVD	digital video disc
EA	each
ECS	Elemental Capture Spectroscopy
EnviroWorks, Inc	EnviroWorks
EES	Earth and Environmental Sciences
FMI	formation microimager
FMU	Facility Management Unit
FSF	Field Support Facility
FTA	Facility Tenant Agreement
ft	feet
g	grams
gal	gallon
gpm	gallons per minute
GPS	global positioning system
hp	horsepower
hr	hour(s)
HSA	hollow-stem auger
ID	inner diameter
IDW	investigation derived wastes
in	inches
KA	Kleinfelder, Inc.
KBr	potassium bromide
LANL	Los Alamos National Laboratory
lb	pounds
mil	1/1000 of an inch
mL	milliliters
NAD	North American Datum
NGVD	National Geodetic Vertical Datum
NGS	natural gamma spectroscopy
NM	not measured
NMED	New Mexico Environment Department
NOI	Notice of Intent

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

NTU	nephelometric turbidity unit
OD	outer diameter
PI	Principal Investigator
PMP	Project Management Plan
psi	pounds per square inch
PVC	polyvinyl chloride
RPF	Record Processing Facility
SAP	Sampling and Analysis Plan
SCFD	Sample Control and Field Document
SMO	Sample Management Office
SOP	Standard Operating Procedures
SSHASP	Site-Specific Health and Safety Plan
TA	technical area
TD	total depth
TDS	Total Dissolved Solids
TLD	triple detector lithodensity
TOC	total organic carbon
µS/cm	microsiemens per centimeter
USACE	United States Army Corps of Engineers
WCSF	waste characterization strategy form
WDC	WDC Exploration & Wells

ABSTRACT

Characterization Well R-4 was installed at Los Alamos National Laboratory (LANL) for the LANL's Groundwater Protection Program as part of the "Hydrogeologic Workplan" (LANL 1998, 59599). The Department of Energy (DOE) through contract with the US Army Corps of Engineers (USACE) directed the installation of Well R-4. The well is intended to provide hydrologic and water-quality data for regional groundwater in the vicinity of potential contaminant sources in Pueblo Canyon. The data will be used with similar data from other wells in the area to improve the conceptual model for geology, hydrology, and chemistry in this wet canyon and provide constraints on numerical models that address contaminant migration in the vadose zone and the regional aquifer.

Pueblo Canyon contains active and inactive potential contaminant sources derived from LANL and town site sources. Well R-4 is located downgradient of the airport landfill and upgradient of the Los Alamos County Sewage Treatment Plant. Coring and drilling activities were conducted from August 28, 2003 through September 26, 2003 at Well R-4. Well R-4 was installed by drilling a borehole into the regional water table and through two perched water zones in the Puye Formation. The boreholes for Well R-4 were sampled to determine water quality and tested to determine hydrologic properties. The well was drilled in two phases. Phase I consisted of collecting continuous core from the surface to a depth of 233 feet (ft) below ground surface (bgs). Core from this borehole was used to characterize vertical contaminant profiles in the vadose zone beneath the canyon floor. In Phase II drilling, a boring was drilled approximately 100 ft into the regional aquifer to a depth of 843 ft bgs.

The initial Phase II Well R-4 borehole was drilled from August 26, 2003 to September 8, 2003. On September 5, 2003, the drilling system became stuck due to excessive slough in the borehole. On September 8, 2003, a decision was made to plug and abandon the initial Well R-4 borehole (with agreement from NMED). Approximately 180 ft of drill pipe and bit assembly and 180 ft of tremie pipe were abandoned in the borehole at 709 ft bgs.

Between September 16, 2003, and September 26, 2003, an offset borehole was drilled to a total depth of 843 ft bgs using air-rotary, fluid-assist air-rotary and mud-rotary drilling methods.

Perched water zones were encountered in the corehole at depths of 110 to 125 ft bgs (Puye Formation), with a potential perched zone at 226 ft bgs (Puye Formation). Two temporary piezometers were installed to monitor perched water conditions. However, both piezometers were dry when sounded on November 25, 2003. The regional zone of groundwater saturation was encountered at a depth of 732 ft bgs in the unassigned formation fanglomerates. Well R-4 was completed at a depth of 792.9 ft bgs with a single screen in the regional aquifer on October 3, 2003.

The stratigraphy encountered during borehole drilling included, in descending order, alluvium (Qal), the Guaje Pumice (Qbog), Puye Formation fanglomerate (Tpf), unassigned pumiceous sediments, and unassigned formation fanglomerates (Tf). Samples of drill cuttings were collected at regular intervals for stratigraphic, petrographic, and geochemical analysis.

Borehole groundwater samples were collected from the uppermost perched zone and from the regional aquifer for analysis of selected organic and inorganic constituents and radiochemical compounds.

1.0 INTRODUCTION

This completion report summarizes the drilling, well construction, well development, and related activities conducted from August 22, 2003 to April 4, 2004 for characterization Well R-4. Well R-4 was drilled and installed at LANL for LANL's Groundwater Protection Program as part of the "Hydrogeologic Workplan" (LANL 1998, 59599), and is located at an inactive emergency aircraft landing strip in Pueblo Canyon, in Technical Area (TA)-74, as shown in Figure 1.0-1.

This report also describes operational activities associated with the site preparation, drilling, installation, development, completion, and testing of Well R-4. The information presented in this report was compiled from field reports and activity summaries generated by Kleinfelder, Inc. (KA), LANL, and subcontractor personnel. Schlumberger provided geophysical data and interpretation. Results of these activities are discussed briefly and shown in tables and figures contained in this report. Detailed analysis and interpretation of geologic, geochemical, and hydrologic data will be included in separate technical documents prepared by LANL.

KA, under contract to the USACE and funded by DOE, was responsible for executing the drilling, installation and sampling activities with technical assistance from LANL.

Well R-4 is designed to provide water-quality and water level monitoring data from the regional aquifer downgradient of potential contaminant sources in Pueblo Canyon. The principal releases of contaminants took place at the former TA-45 site of radioactive wastewater treatment plant WWTP discharges. Known contaminants from former TA-45 include tritium, isotopes of uranium and plutonium, strontium-90, cesium-137, and gross-alpha radiation. In addition, Los Alamos County operated a sewage treatment plant in upper Pueblo Canyon (known as the Pueblo Sewage Treatment Plant) until the current Los Alamos County Sewage Treatment Plant came on-line in 1963. Effluent from these past sources likely supported sustained saturated conditions throughout the mid-reach of Pueblo Canyon. This alluvial groundwater may have provided a source for infiltration to intermediate perched groundwater zones and the regional aquifer.

Data from Well R-4 will be evaluated in conjunction with data from other hydrologic work plan wells. The evaluation will form the technical basis for the design of a groundwater monitoring system, if needed. Water quality, geochemical, hydrologic, and geologic information obtained from Well R-4 will augment knowledge of regional subsurface characteristics and distribution of any contaminants downgradient of potential release sites.

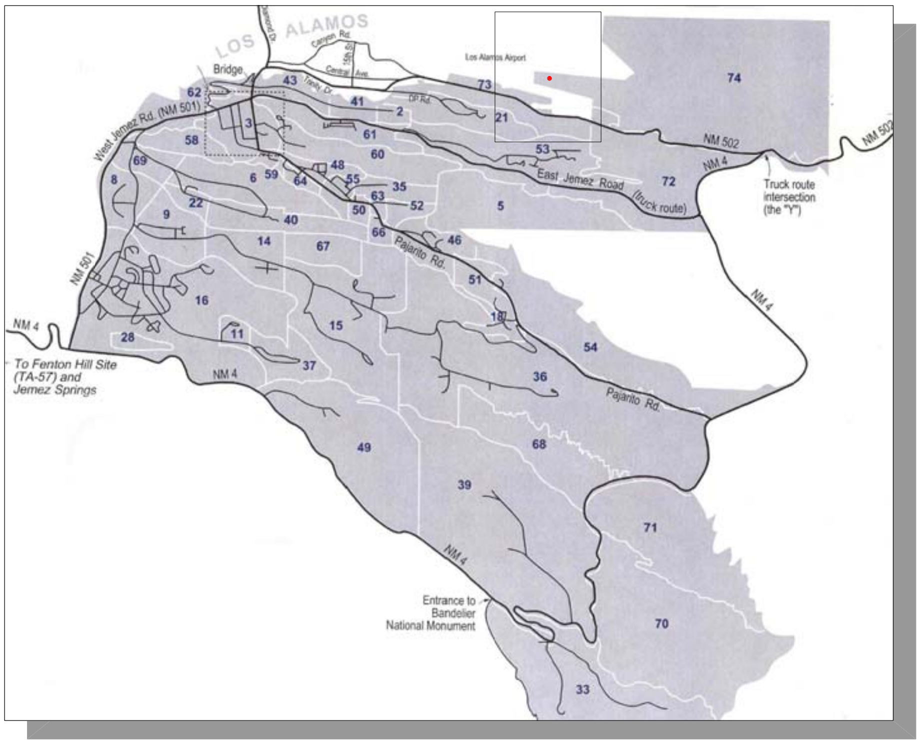
2.0 PRELIMINARY ACTIVITIES

Preliminary activities at Well R-4 included administrative work and site preparation.

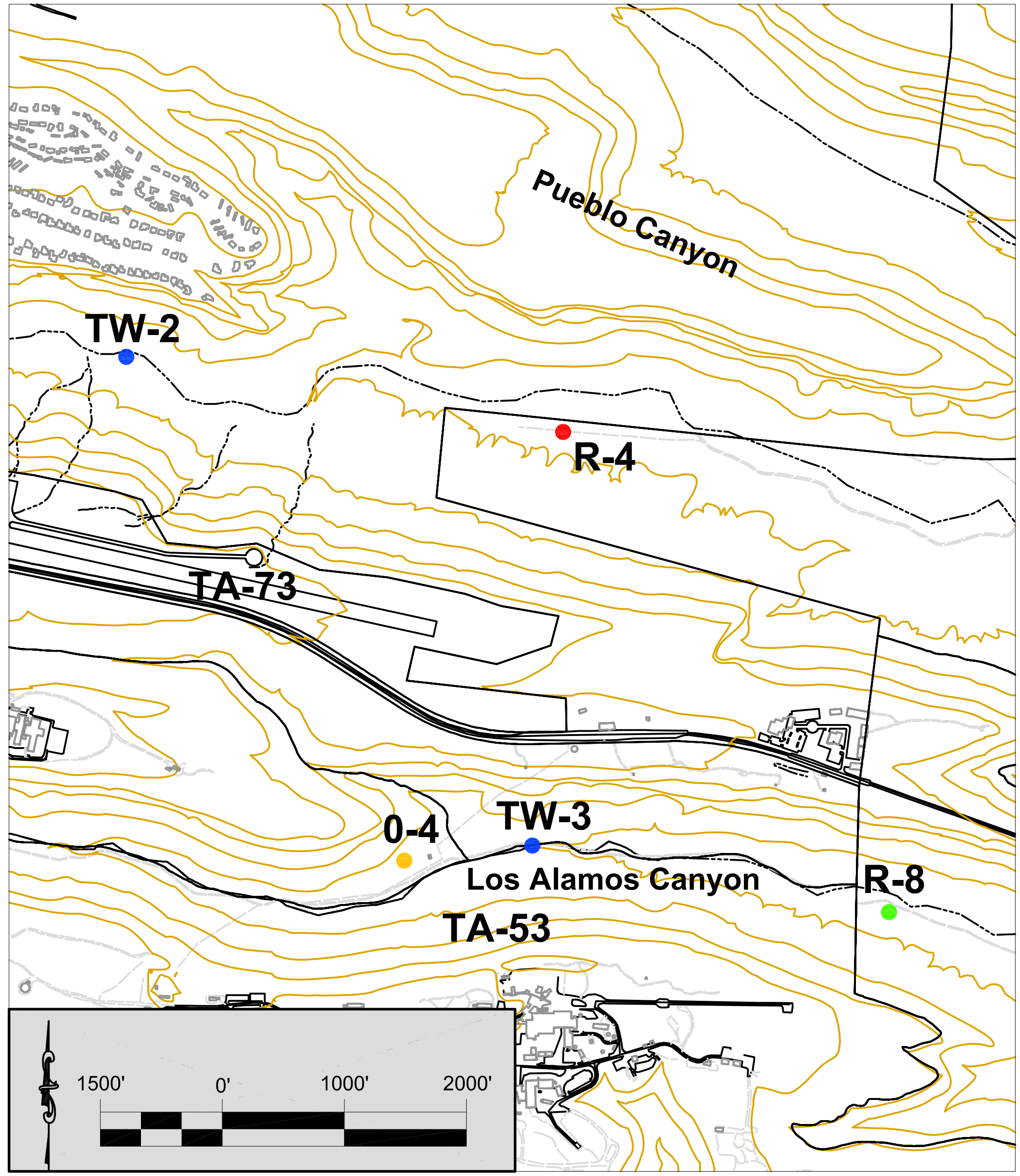
2.1 Administrative Preparation

KA received contractual authorization to start administrative preparation tasks in the form of a notice to proceed on June 16, 2003. As part of this preparation, KA developed a Project Management Plan (PMP), a Contractor's Quality Management Plan (CQMP), a Site-Specific Health and Safety Plan (SSHASP), and a Drilling Plan (DP) for the work at Well R-4. All necessary permits and access agreements were obtained prior to beginning fieldwork.

Site Location



Los Alamos National Laboratory Boundary



Production Well
Observation Well
R-4 Characterization Well
Existing R Characterization Wells

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Drawn By: C. Landon	Date: February 2004	SITE LOCATION MAP Well R-4 Location LANL Well Program Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 1.0-1
Project No.: 37151	Filename: FIGURE 1.0–1		
Scale: 1" = 2000'	Revision: 2		

Note: R-4 Well Identification Modified from Proposed R Characterization Well Location Map Provided by Los Alamos National Laboratory

2.2 Site Preparation

EnviroWorks, Inc. (EnviroWorks) was subcontracted by KA to conduct site preparation. Activities included site clearing, access road improvement, construction of a drill pad, and construction of a lined borehole-cuttings containment area. Site preparation began on August 21, 2003 and was completed on August 22, 2003.

The Well R-4 site was initially cleared of vegetation. The drilling pad was developed through grading an area approximately 220 ft by 60 ft. A primary layer of crushed concrete was distributed over the drill pad and equipment storage areas. To store Well R-4 drilling fluids and borehole cuttings, a 20 ft wide by 70 ft long by 7 ft deep borehole-cuttings containment area was excavated along the southern pad boundary and lined with 10-mil polyethylene. Two 12 ft by 45 ft secondary containment areas were lined with 6-mil polyethylene and surrounded by straw bales to accommodate two 20,000 gallon (gal) tanker trailers used for storing drilling fluids pumped from the borehole-cuttings containment area and development water, respectively. Drill pad construction was completed with additional layers of graded and compacted crushed concrete. Safety barriers and signs were installed around the borehole-cuttings containment area and at the site entrance. Office and supply trailers, generators, and safety lighting equipment were moved to the site during subsequent mobilization of drilling equipment. Base course gravel was also placed on the access road as necessary. Equipment necessary for the completion of the drilling project was situated at the work site to provide a safe, secure work site. Orientation and placement of the equipment was dependent on borehole location, landing strip configuration, and adjacent county boundaries.

Sediment from site preparation work was controlled on-site through the use of silt fences. In accordance with the 401/404 permit that was issued for the project, no sediments were added to the nearby stream channel or access road crossing.

3.0 SUMMARY OF DRILLING ACTIVITIES

The goal of Phase I drilling was to identify any perched water zones and to collect continuous rock core samples for geologic characterization for determination of moisture, anions, stable isotopes, radionuclides, metals, and tritium distributions in the upper part of the geologic section. The maximum planned depth for Phase I drilling was 300 ft bgs. Groundwater samples were to be collected if sufficient quantities of groundwater were encountered in perched zones. Phase II drilling objectives were to: (1) collect drill cuttings to characterize encountered geologic formations, (2) collect water samples from perched and regional groundwater zones, and (3) complete a borehole for geophysical logging, and install a well for collection of groundwater samples in the regional aquifer. The planned TD for Phase II drilling was approximately 820 ft bgs, estimated to be approximately 100 ft into the regional aquifer.

Drilling activities were performed generally in one 12-hr shift per day, seven days a week. Coring and drilling activities occurred from August 26, 2003 through September 26, 2003. A tabulated chronology of drilling and other on-site activities is presented as Table 3.0-1.

3.1 Phase I Drilling Activities

Coring activities at Well R-4 were conducted from August 28, 2003, through September 5, 2003. On August 28, 2003, KA mobilized a Strata Star SS15 auger drill rig and support equipment to

TABLE 3.0-1. CHRONOLOGY OF ACTIVITIES FOR WELL R-4
LOS ALAMOS DEEP WELL DRILLING PROGRAM

TASK DESCRIPTIONS	DATE																											
	Aug-03				Sep-03				Oct-03				Nov-03				Dec-03				Jan-04				Feb-04			
SUMMARY OF DRILLING ACTIVITIES																												
SITE PREPARATION ACTIVITIES			**8/21-22**																									
CORE HOLE DRILLING AND SAMPLING				**8/28**	**9/5**																							
Mobilization				8/28																								
Continuous Coring				8/28	9/5																							
Piezometer Construction					9/5																							
BOREHOLE DRILLING AND SAMPLING				**8/26**				**9/26**																				
Mobilization				8/26																								
Air Rotary				8/27				9/26																				
Mud Rotary																												
Groundwater Sampling					9/4	9/9																						
BOREHOLE GEOPHYSICS								**9/27**																				
Schlumberger Logging								9/27																				
WELL DESIGN AND CONSTRUCTION								**9/28**	**10/3**																			
WELL DEVELOPMENT									**10/6**	**10/10**																		
GROUNDWATER WELL SAMPLING										**10/10**																		
HYDROLOGIC TESTING																		**12/16**	**12/23**									
SITE RESTORATION												**10/31**													Not completed to date.			
REPORT PREPARATION													**11/1**															**2/25**

Notes: Site restoration activities will begin after receiving NMED discharge approval.

the Well R-4 site and commenced continuous coring operations on August 29, 2003. Coring took place without the use of drilling fluids to minimize impact to the natural concentrations of moisture and soluble anions. Core sampling was conducted through the alluvium and Guaje Pumice Bed and into the upper Puye Formation to a depth of 68 ft bgs. At this depth, KA switched to split-spoon sampling methods utilizing a hammer to advance a 2-ft long split-spoon sampler. This method was used from 68 ft bgs to the TD of the corehole at 233 ft bgs. On September 2, 2003, while collecting a sample from the 95.5 ft to 97.5 ft interval, the sample spoon sheared off from the drill rod. The sample spoon was retrieved with a fishing tool after augering over the sampler to 105 ft bgs. Sampling resumed and continued to a depth of 164 ft bgs. On September 3, 2003 sampling advanced to 227.5 ft bgs.

On the morning of September 4, 2003 water level readings were attempted in the corehole; no water was encountered. When drilling resumed, hard drilling conditions were encountered in Puye gravels between 227.5 ft and 230 ft bgs. The augers were removed from the corehole to check the condition of the cutting head, which was observed to be in good condition. The LANL natural gamma logging tool was run inside the augers; no water was observed in the corehole. Drilling operations continued until auger refusal was encountered at 233.0 ft bgs within the Puye Formation.

No groundwater was encountered in the upper alluvial sediments during Phase I drilling. Potential perched water conditions were observed between 110 ft to 125 ft bgs and wet conditions were observed between 226 ft to 230 ft bgs. Consequently, the corehole was used to install two temporary piezometers to observe and monitor potential perched water conditions. (See Section 7.3 for further discussion.)

3.2 Phase II Drilling Activities

On August 22, 2003, during Phase I operations, Albuquerque Caisson installed and cemented in place, a 16-in, outside diameter (OD) surface casing through the alluvium and approximately 10 ft into the Puye Formation to a depth of 60 ft bgs. The surface casing was offset approximately 115 ft east of the Phase I corehole enabling simultaneous coring and deep drilling operations. Phase II drilling operations were conducted from August 26 through September 26, 2003.

On August 26, 2001, WDC Exploration & Wells (WDC) mobilized a Failing® Speed Star 50K-CH drill rig and support equipment to the site and inserted 40 ft of 13⅜-in OD steel conductor casing inside the existing 16-in steel surface casing. The following day WDC advanced the 13⅜-in drill casing to 80 ft bgs and continued drilling open-hole utilizing a 12¼-in tricone button bit with air-rotary techniques in the upper Puye Formation, to a depth of 200 ft bgs.

On August 28, 2003, WDC continued drilling into the Puye Formation using the 12¼-in tricone bit and fluid assisted air-rotary techniques to 243 ft bgs where WDC switched to a 12¼-in DTH hammer bit. The following day the borehole was advanced to 270 ft bgs where the bit and DTH assembly became stuck due to the accumulation of approximately 47 ft of slough above the drill bit. WDC elected to trip in 2-in tremie pipe to 214 ft bgs, about 6 ft above the top of the slough and airlift the slough from above the drill bit to the surface. This strategy was successful and, once freed, the drill string was tripped out of the borehole.

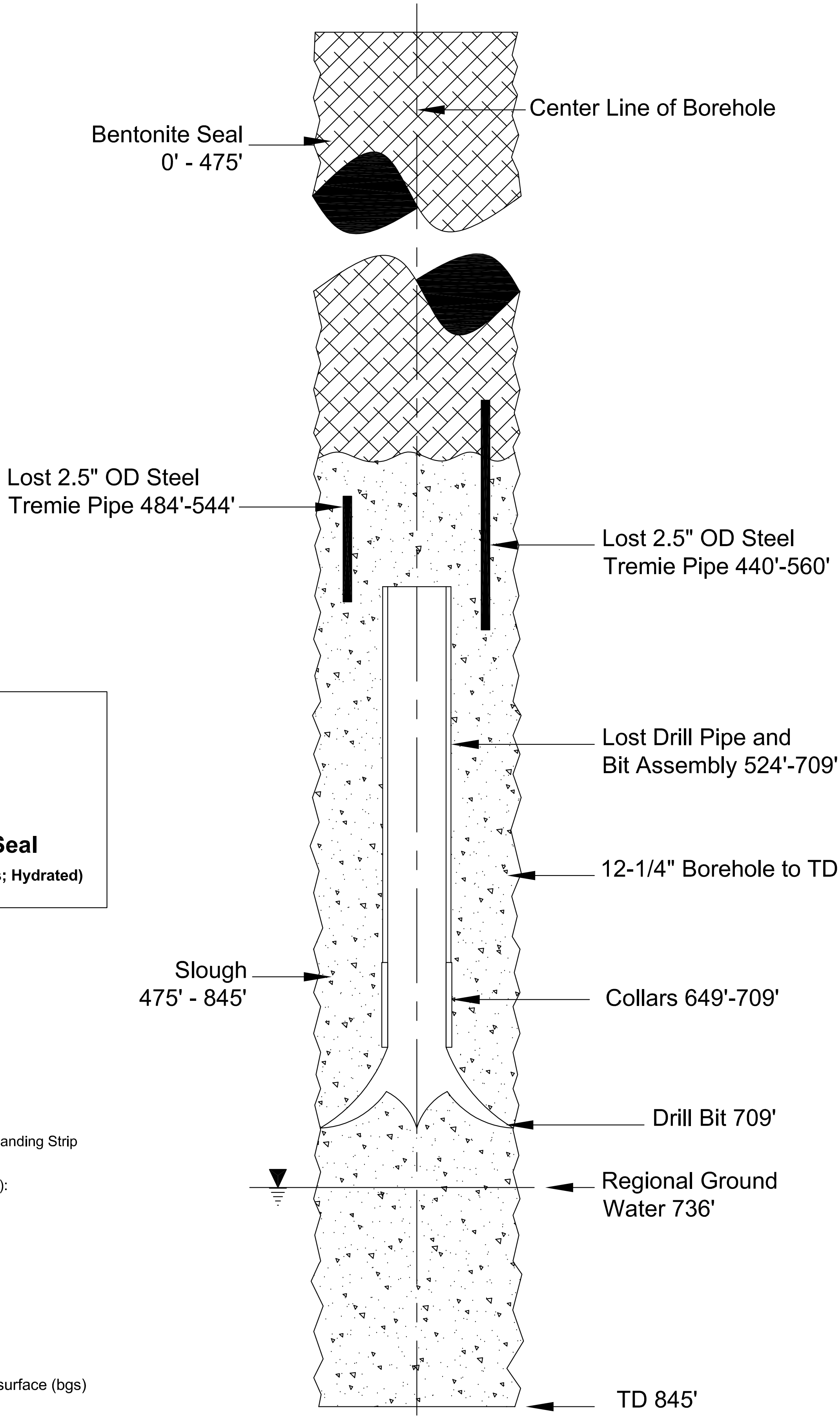
On August 30, 2003, WDC switched to a 12¼-in tricone drill bit and resumed drilling at 270 ft bgs using air-rotary drilling technique assisted with drilling fluids consisting of QUIK-FOAM®, EZ-MUD®, and potable water.

On September 2, 2003 the static water level for the regional aquifer was measured at 736 ft bgs when the depth to the bottom of the borehole measured 753 ft bgs. An attempt was made to collect a sample of groundwater with a bailer. Retrieving the groundwater sample with a bailer failed due to excess slough and sediment in the water. After cleaning residual cuttings from the borehole and further advancing the borehole to 845 ft bgs, drilling was halted to collect a groundwater sample. A 5-gal cubitainer of groundwater was collected by airlifting the water to the surface and obtaining it from the cuttings discharge line. The sample was submitted for analysis on September 4, 2004.

WDC experienced difficulty tripping out the drill stem from 845 ft bgs and had to back-drill up to make progress. With the drill bit at 721 ft bgs, the hydraulics on the drill rig overheated and activities were halted for the day. On the morning of September 3, 2003, WDC made repairs to the hydraulic system and resumed attempts to free the drill stem. The drill stem could not be pulled past 710 ft bgs and operations ceased for the day. The following day, WDC tagged the top of slough and determined there was approximately 235 ft of slough above the drill bit preventing the drill stem from being tripped out. WDC tripped in a 2-in tremie pipe to 480 ft bgs and began airlifting slough from the borehole. The process of airlifting and lowering tremie pipe continued in 20 ft increments for five hours and was terminated at 600 ft bgs. On September 5, 2003, airlifting was resumed and then halted at 620 ft bgs. The tremie pipe was tripped out of the borehole and repeated attempts to pull up the drill stem failed. The tremie pipe was reinserted into the borehole and airlifting resumed, continuing to a depth of 680 ft bgs. On the morning of September 6, 2003, after working until midnight trying to free the drill stem without success, the tremie pipe was tripped out of the borehole and it was discovered that the lower 120 ft of tremie pipe had sheared off. WDC attempted to view the lost tremie pipe with the down-hole video camera on September 6, 2003. On September 7, 2003, efforts to fish-out the lost tremie pipe sections resulted in the loss of an additional 60 ft of pipe. Subsequent efforts to pull the drill string were unsuccessful. On September 8, 2003, WDC, in agreement with the DOE and NMED project representatives, decided to break off the drill stem and plug and abandon the borehole. A total of 500 feet of drill stem was retrieved. Materials left in the borehole included 185 ft of drill pipe, a drill bit assembly consisting of a 12¼ in tricone drill bit and its associated collars, and 180 ft of tremie pipe. The lost drill stem interval is from 709 ft to 524 ft bgs, approximately 27 ft above the regional water table. Top of slough was last tagged at approximately 475 ft bgs. On September 7, 2003 the borehole was plugged and abandoned according to NMED-approved procedures. Figure 3.2-1 shows the configuration of the plugged and abandoned borehole and indicates the depths of the various components including lost tremie pipe, lost drill pipe and bit assembly and the bentonite seal.

WDC resumed operations at R-4 on September 16, 2003 by moving the drill rig and support equipment to a new location approximately 120 ft west of the plugged and abandoned borehole and approximately 20 ft west of the corehole.

WDC advanced 13⅜-in steel surface casing from ground surface and set it at 40 ft bgs using air-rotary casing hammer techniques. Open-hole air-rotary drilling with foam started at 40 ft bgs using a 12¼-in mill tooth tricone bit and continued to 244 ft bgs on September 18, 2003, when



LEGEND:

- **Slough**
- **Bentonite Seal** **(Bentonite Chips; Hydrated)**

Location: At inactive emergency Landing Strip
in Pueblo Canyon; TA-74

Survey Coordinates/Elevations (ft):
- Coordinates: NAD83
- Elevation: NGVD29

Description: Abandoned Borehole
Northing: 1776516.6
Easting: 1639412.7
Elevation: 6574.46

Keyed Notes:

1. All depths are below ground surface (bgs)

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Drawn By: C. Landon	Date: January 2005
Project No.: 37151	Filename: Figure 3.2–1
Scale: Not To Scale	Revision: 1
Reviewed By: F. Schelby	Approved By: A. Kuhn

Abandoned Borehole Status - R-4
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
3.2-1

L:\2003\Projects\37151 DOE Deep Wells\4.0 – Project Technical Information\R-4\4.3 – Project Deliverables\Well Completion Report\Superceded\Figure 3.2-1 Revised January.dwg progress was impeded below 261 ft bgs by sidewall caving. Mud-rotary techniques were implemented to mitigate the sidewall stability problems. Mud-rotary drilling continued to total depth at 843 ft bgs in Phase II. Drilling activities were completed on September 26, 2003.

3.2.1 Drilling Fluids

Tables 3.2.1-1 and 3.2.1-2 summarize the types and quantities of drilling fluids introduced in and recovered from the abandoned and completed borehole, respectively.

Table 3.2.1-1
Drilling Fluids Introduced and Recovered–
Abandoned Borehole Well R-4

Materials	Units	Amounts
QUIK FOAM®	Gallon	138
EZ-MUD®	Gallon	23
Potable Water	Gallon	25,900
Recovered Fluids	Gallon	21,991

Note: Data collected from Driller's Daily Reports.

Table 3.2.1-2
Drilling Fluids Introduced and Recovered–
Completed Borehole Well R-4

Materials	Units	Amounts
QUIK FOAM®	Gallon	45
SODA ASH	Gallon	150
EZ-MUD®	Gallon	10
AQUA GEL®	Lbs	10,075
PAC®-L	Gallon	250
Potable Water	Gallon	25,700
Recovered Fluids	Gallon	9,425

Note: Data collected from Driller's Daily Reports.

4.0 SAMPLING AND ANALYSIS OF DRILL CORE AND GROUNDWATER AT WELL R-4

Core samples were collected from the alluvium, Guaje Pumice Bed, and upper portions of the Puye Formation. Samples of core were analyzed for cations, anions, metals, and radionuclides for characterization purposes. Eleven samples of core were collected from the vadose (unsaturated) zone during drilling from 5 ft to 220 ft bgs. Approximately 500 grams (g) to 1,000 g of core or cuttings samples were placed in appropriate sample jars in protective plastic bags before they were analyzed by EES-6, Coastal Science Laboratories, Inc., and Severn–Trent Laboratories (STL), Inc. The results will be reported in a future investigation report for Pueblo Canyon.

During drilling operations, alluvial groundwater was not encountered at borehole R-4 and no water samples were collected for analyses. A perched intermediate groundwater zone was encountered within the Puye Formation fanglomerates at 110 ft bgs and a screening groundwater sample was collected from 114 ft to 125 ft bgs on September 9, 2003. The regional water table was encountered at 736 ft bgs and a groundwater sample was collected from Well R-4 for chemical and radiochemical analyses after well development on October 10, 2003. Analyses from these samples are presented in Appendix A.

A groundwater sample from the regional aquifer was collected from the completed Well R-4 (screened interval 792.9 – 816 ft bgs) following development. The sample was collected primarily to determine if potential contaminants were present in the regional aquifer. Major potential contaminants of concern at R-4 include mobile solutes such as nitrate, perchlorate, uranium, and tritium. Analytical results from this sample are presented in Appendix A.

5.0 BOREHOLE GEOPHYSICS

Using LANL-owned and subcontractor-owned tools, KA and Schlumberger performed borehole logging operations at Well R-4.

5.1 Kleinfelder-Supported Geophysical Logging

Video and natural gamma logging, using down-hole tools provided by LANL, was performed through the auger-cased corehole to detect water in the casing and to characterize the lithology of the rock units penetrated by the corehole. Video logging was also used in the abandoned borehole to view the lost tremie pipe (logging was not recorded). Video logging was not performed in the completed borehole. Table 5.1-1 summarizes the well logging surveys conducted in Well R-4 by Schlumberger and video logging performed by KA/LANL.

Table 5.1-1
Borehole and Corehole Well Logging Surveys Conducted in Well R-4

Operator	Date	Method	Cased Footage (ft bgs)	Open-hole Interval (ft bgs)	Remarks
KA/LANL	September 4, 2003	Natural Gamma	0-230	N/A	Auger-cased corehole, natural gamma log to 230 ft bgs
KA/LANL	September 6, 2003	Video camera	N/A	0-173	Open corehole, auger tripped out
Schlumberger	September 27, 2003	Logging suite[(1)]	0-40	40-840	Schlumberger borehole logging conducted to TD prior to well installation

[(1)] Schlumberger suite of borehole logging surveys included triple detector litho-density, array induction tool, epithermal compensated neutron tool, elemental capture spectrometry, full-bore formation microimager, combinable magnetic resonance and natural gamma spectrometry.

5.2 Schlumberger Geophysical Logging

Schlumberger personnel conducted geophysical logging in the second Well R-4 borehole on September 27, 2003.

The primary purpose of the Schlumberger logging was to characterize the conditions in the hydrologic units penetrated by the Well R-4 borehole, with emphasis on gathering moisture distribution data, identifying possible perched water zones, measuring capacity for flow (porosity and moisture), and obtaining lithologic/stratigraphic data. Secondary objectives included evaluating borehole geometry and determining the degree of drilling fluid invasion along the borehole wall.

Schlumberger personnel ran a suite of geophysical logging tools in the cased (0 – 40 ft bgs) and uncased (40 – 843 ft bgs)borehole; the suite include the following tools:

- Array Induction Tool, version H (AITH^{TM}), measures formation electrical resistivity and borehole fluid resistivity, thus evaluating the drilling fluid invasion into the formation, the presence of moist zones away from the borehole wall, and the presence of clay-rich zones.
- Triple detector Litho-Density (TLD^{TM}) measures formation bulk density related to porosity, photoelectric effect related to lithology, and borehole diameter using a single-arm caliper.
- Natural Gamma Spectroscopy (NGS^{TM}) measures spectral and overall natural gamma ray activity, including potassium, thorium, and uranium concentrations, thus evaluating geology and lithology.
- Elemental Capture Spectroscopy (ECS^{TM}) measures concentrations of hydrogen, silicon, calcium, sulfur, iron, potassium, titanium, and gadolinium to characterize mineralogy, lithology, and water content of the formation.
- Epithermal Compensated Neutron Tool, model G (CNTG^{TM}) measures volumetric water content beyond the casing to evaluate formation moisture content and porosity.
- Full-Bore Formation Micro-Imager (FMITM) captures electrical conductivity images of the borehole wall and measures the borehole diameter with a two-axis caliper to evaluate geologic bedding and fracturing, including strike and dip of these features, fracture apertures, and rock textures.
- Combined Magnetic Resonance (CMR^{TM}) measures the nuclear magnetic resonance response of the formation in open hole for evaluating total and effective water-filled porosity of the formation near the borehole wall and for estimating pore size distribution and hydraulic conductivity.

Additionally, a calibrated natural gamma tool was used to record gross natural gamma-ray activity with each logging method (except the NGSTM run) to correlate depth runs between each of the surveys conducted.

The Schlumberger interpretive logging report and the geophysical logs, compiled as a montage, can be found in Appendix B on the compact disc (CD) on the inside back cover of this report.

6.0 LITHOLOGY AND HYDROLOGY

A preliminary assessment of the geologic characterization and the hydrologic features encountered during drilling of the corehole and the abandoned borehole drilled at Well R-4 is presented below. Groundwater occurrences are discussed on the basis of drilling evidence and geophysical logging data. Geologic contact zones were provided by LANL's EES-6 staff.

6.1 Stratigraphy and Lithologic Logging

Rock units and stratigraphic relations, interpreted primarily from visual examination of core samples and interpretation of geophysical data, are briefly discussed in order of younger to older occurrence. A schematic diagram of the stratigraphy at Well R-4, as well as summary data is shown in Figure 6.1-1. A lithologic log for Well R-4 borehole is provided in Appendix C.

Alluvium (0 to 40 ft bgs)

From 0 – 40 ft bgs unconsolidated alluvium (Qal), representing stream channel sediments in Pueblo Canyon, was identified. These clastic deposits, comprising tuffaceous silty sands and gravels, are composed of detritus derived from the Bandelier Tuff and the Tschicoma Formation.

Guaje Pumice Bed of the Bandelier Tuff (40 to 50 ft bgs)

In borehole R-4 the Bandelier Tuff is locally represented exclusively by the Guaje Pumice Bed (Qbog). Core samples indicate that the interval from 40 to 50 ft bgs is comprised of altered pumice and clay representing air-fall tephra. The unit is strongly altered or weathered and consists of crystal rich pumices that have been partially altered to white and dark brown, waxy clay. Altered pumices contain quartz, fieldspar, and possible pyroxene phenocrysts and fibrous structure with relic vesicularity.

Puye Formation (50 to 380 ft bgs)

Tuffaceous and volcaniclastic sedimentary rocks representing fanglomerate deposits of the Puye Formation (Tpf) are recognized in the interval from 50 ft to 380 ft bgs in the borehole. Cuttings in this interval are predominantly made up of gravels and sand composed of Tschicoma-derived volcanic rocks (porphyritic dacite and lesser andesite) and minor amounts of tuffaceous quartz and sanidine crystals (probably slough from higher in the borehole). Coarse detrital materials are typically subangular to subrounded.

Pumiceous Deposits – Unassigned (380 to 440 ft bgs)

Pumice-bearing sediments (Tpp) occur in the interval from 380 ft to 440 ft bgs. At present, it is uncertain whether these pumiceous deposits occur within, or underlie, the Puye Formation. Therefore, they have not yet been assigned to any stratigraphic unit. Drill cuttings representing the interval indicate sands and gravels that are typically made up of 10 to 50% pumice. Locally, however, dacitic and andesitic detrital components, likely derived from Tschicoma sources, may comprise as much as 80% of chip samples. Pumice occurs as both fresh-appearing, white vitric clasts and as orange-brown clay-altered varieties.

Location: At inactive emergency Landing Strip
in Pueblo Canyon; TA-74

Survey Coordinates / Elevations:
- Coordinates: NAD83
- Elevation: NGVD29

Description: Brass Marker in Concrete Pad
Northing: 1776530.28
Easting: 1639287.98
Elevation: 6577.49

Description: Well Casing
Northing: 1776528.00
Easting: 1639289.98
Elevation: 6579.46

Coring:
(0'-68') Continuous Sampler
(68'-233') Split Spoon

Drilling:
(0'-40') 13-3/8" Air Rotary Casing Hammer
(40'-843') 12.25" Milltooth Tri-Cone
(40'-266') Fluid-assisted Air Rotary
(266'-843') Mud Rotary

Data Collection:
- Hydrologic Properties:
  Constant Discharge
  Pump Test Completed: 01/06/04
- Cores/Cuttings submitted for geochemical and contaminant characterization: 11
- Ground Water Samples Submitted
  Perched Ground Water - 9/9/03 (114'-125')
  Regional Ground Water - 10/10/03 (792.9'-816')
- Geologic Properties: Cuttings submitted for
  Minerology, petrography, and chemistry: 7

Corehole Logs:
- Corehole: 0'-233'
- Natural Gamma Tool (LANL tool): 0'-230'

Borehole Logs:
- Video (LANL tool): 0'-173'
- Lithologic: 0'-843'
- Schlumberger logs (9/27/03):
  Top of Drilling Fluid at 18' bgs
  Compensated Neutron Tool: 40'-842'
  Triple Litho-Density: 40'-842'
  Array Induction Tool: 40'-836'
  Elemental Capture Spectroscopy: 40'-838'
  Natural Gamma Spectroscopy: 40'-836'
  Combinable Magnetic Resonance: 100'-838'
  Full-Bore Formation Micro Imager: 100'-838'

Core Drilling: 8/28/03 - 9/5/03

Piezometers PZ#1 and PZ#2 completed: 9/5/03

Rotary Drilling: 8/22/03 - 9/26/03

Well Constructed: 9/28/03 - 10/3/03

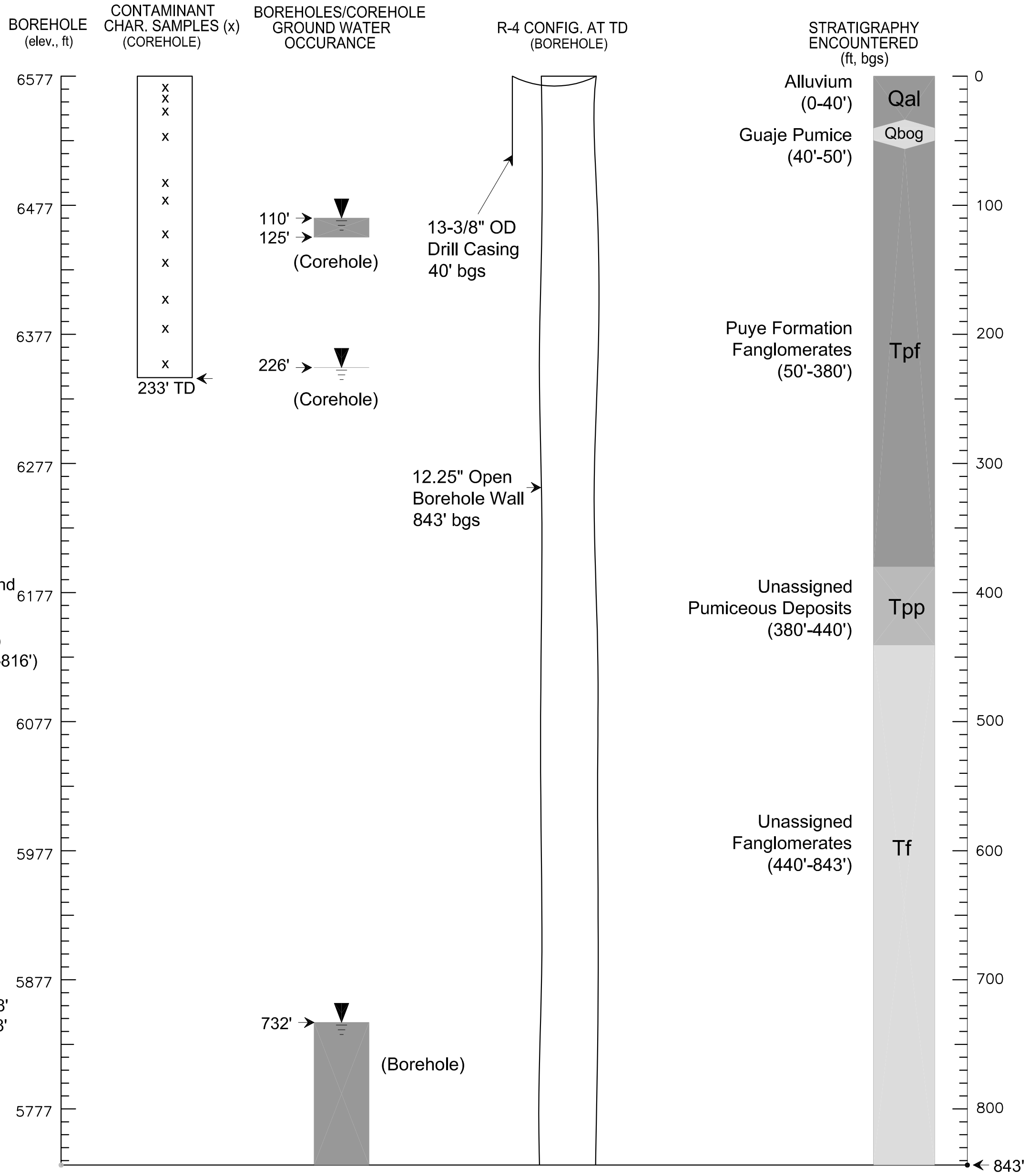
Well Developed: 10/6/03 - 10/10/03

Well Completion:
- Casing: 4.46" ID / 5.0" OD A304 stainless steel casing with external couplings
- Number of Screens:
  One (1) 4.46" ID / 5.27" OD wire wrapped 0.020" slot stainless steel with external couplings
- Screen Interval: 792.9' - 816' bgs

Well development performed by swabbing, bailing, and pumping.
Total Volume Purged, including Aquifer Testing: 56,347 gal.

Hydrologic Testing
Total Volume Removed: 42,197 gal.

Geologic contacts for R-4 were determined from core samples, cuttings, and geophysical logs.



Keyed Notes:

1. Coordinates - NM State Plane Grid Central Zone (North America), Datum - 1983 (NAD83); expressed in feet
2. Elevations - National Geodetic Vertical Datum (NGVD29); expressed in feet above mean sea level
3. bgs - below ground surface
4. TBD - to be determined
5. Both piezometers were dry when sounded on 11/25/03.

KLEINFELDER

Drawn By: C. Landon	Date: January 2005
Project No.: 37151	Filename: Figure 6.1-1
Scale: Not To Scale	Revision: 1
Reviewed By: F. Schelby	Approved By: A. Kuhn

Well Summary Data Sheet for R-4
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
6.1-1

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Tertiary Fanglomerate - Unassigned (440 to 843 ft bgs)

Clastic sediments encountered from 440 ft to 843 ft bgs are preliminarily classified as unassigned formation fanglomerates (Tf). These sand and gravel deposits, dominantly comprised of volcanic detritus, are believed to pre-date the Puye Formation. Cuttings in the upper part of the interval, from 440 to 605 ft bgs, typically contain subangular to subrounded gravel clasts dominantly comprised of dacite and andesite, up to 25% detrital pumice, and 3 to 5% white and pink Precambrian quartzite. The lower fanglomerate interval, from 605 to 843 ft bgs, is made up of basalt and dacite, minor pumice, and trace amounts of quartzite and quartz-mica schist.

6.2 Groundwater Occurrences and Characteristics

6.2.1 Introduction

Three anticipated perched saturation zones and the regional aquifer were identified in the SAP (Sampling and Analysis Plan) for Drilling and Testing Characterization Wells R-2, R-4, R-11, and R-26 (July 2003). The first perched zone was predicted to be in the alluvium, between 0 and 10 ft bgs, the second at the base of the Guaje Pumice Bed between 35 ft and 45 ft bgs, and the third, in the upper Puye Formation between 100 and 200 ft bgs. Regional groundwater saturation at Well R-4 was predicted to occur in the lower fanglomerates (Tf) at an estimated depth of 720 ft bgs.

6.2.2 Perched Zones

No perched saturated zones were observed in the alluvium or near the base of the Guaje Pumice Bed during Phase I coring. Two wet zones were observed from 110 ft to 125 ft bgs and from 226 ft to 230 ft bgs. Two temporary nested piezometers were installed in the corehole to monitor perched water conditions. In the west (shallow) piezometer, static water level was recorded at 114 ft bgs and a sample was collected for chemical analysis. No water was captured in the east (deep) piezometer. No other saturated zones were identified above the regional aquifer. Soundings of the piezometers on November 25, 2003 showed that both piezometers were dry.

To assist in the identification of perched water zones, a potassium bromide (KBr) tracer solution was added to drilling fluids while advancing the initial Phase II borehole between 45 ft and 220 ft bgs. A comparison of the KBr concentration in the injected fluids in the trough and the extracted fluids in the cuttings is shown in Figure 6.2.2-1. Depths where the KBr concentration is lower in the extracted cuttings fluid than expected are noted as potential perched water zones. Inflow of water from the formation is assumed to be diluting the KBr concentrations. Data presented in Figure 6.2.2-1 indicates the presence of a perched water-bearing zone in the borehole at approximately 100 ft bgs and 120 ft bgs. This supports the observation of perched water in the nearby corehole between 110 ft and 125 ft bgs.

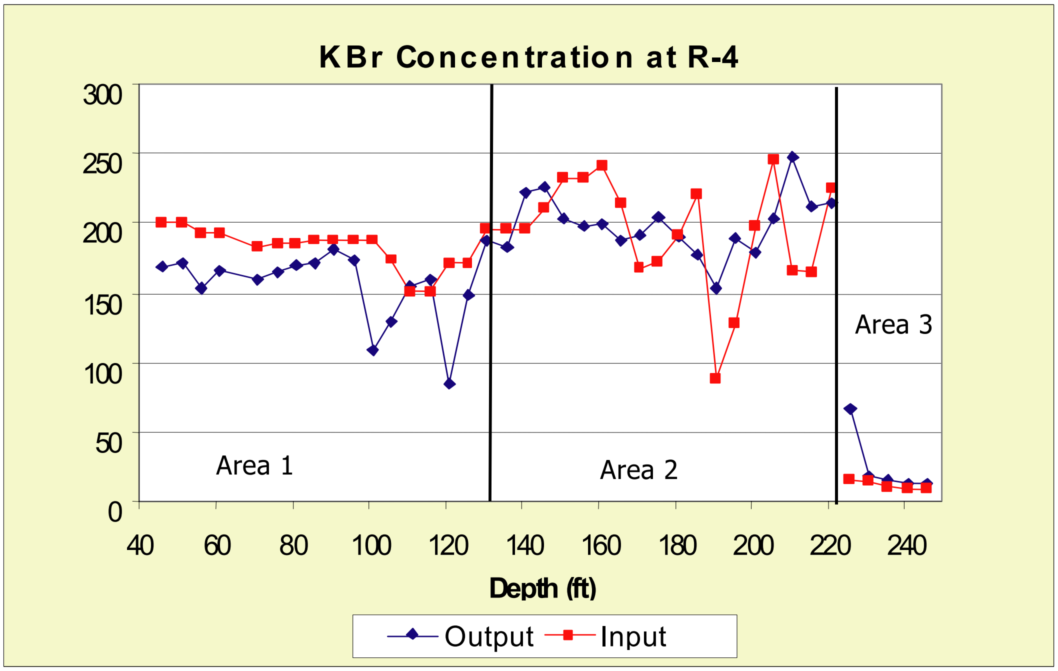


Figure 6.2.2-1. KBr Concentrations in Borehole at Well R-4

In the initial R-4 Phase II borehole, the KBr was added to the input in a 180 gallon trough while water and foam solution were mixed just before injection downhole. The input concentration ranged from 90 ppm to 245 ppm. As a result of the variability in the input concentration, the procedure was changed to adding the KBr to a larger supply of water. Each time the tracer was added to the trough an input sample was taken. A sample was also taken every 5 ft of drilling from the output fluid.

In Area 1 of the graph, the KBr input concentration remains fairly constant. Two negative output peaks can be seen, one at approximately 100 ft bgs and 120 ft bgs, respectively, where saturated zones were observed in the adjacent corehole. Area 2 of the graph displays the variability of the input concentration that does not allow for comparison to the output concentration. Since KBr was no longer added to the system below 220 ft bgs, KBr values in Area 3 are not valid. Therefore, confirmation of the perched water zone from 220 ft to 230 ft bgs is not possible.

According to the logs provided by Schlumberger, a possible zone of movable water was observed in the completed borehole from 374 ft bgs to 444 ft bgs. Physical evidence of this potential mobile water zone was not encountered during the drilling of either borehole.

6.2.3 Regional Aquifer

The regional water table was first observed in the lower fanglomerates (Tf) at a depth of 736 ft. when the bottom of the borehole was at a depth of 755 ft. After a 14-hr stabilization period, static water level was measured at 736 ft bgs. After Well R-4 was completed and developed, the static water level was measured at 732 ft bgs.

7.0 WELL DESIGN AND CONSTRUCTION

Installation of the well at R-4 began on September 28, 2003 and was completed on October 3, 2003. In addition, two (2) temporary nested piezometers were installed in the corehole to monitor perched water zones.

7.1 Well Design

Well R-4 was designed in accordance with Section 2.2 of KA's Contractor's Quality Management Plan (CQMP). DOE, LANL, and KA gathered information from geophysical logs, borehole geologic samples, water-level data, field water-quality data, and field observations to determine the screen placement interval for Well R-4. Approval of the well design was received from NMED prior to well construction. The well was designed to monitor potential contaminants in the uppermost productive zone of the regional aquifer. The screened interval in Well R-4 is 792.9 ft to 816 ft bgs.

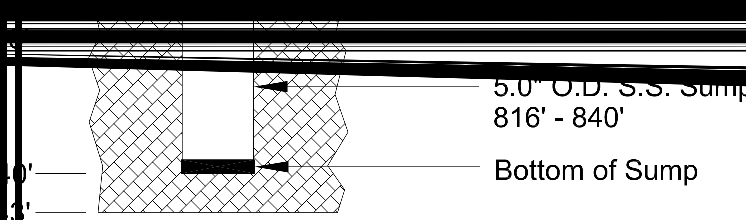
7.2 Well Construction

Well R-4 was constructed using 4.46-in ID/5.0-in OD type A304 stainless-steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. Prior to installation the stainless-steel well components were cleaned at the well site using a high-pressure steam cleaner and scrub brushes. Stainless-steel well casing and screen sections are connected by threaded couplings. Two 10-ft lengths of 5-in OD compatible, rod-based, wire-wrapped 0.020-in continuous slot well screens were set at 792.9 ft bgs to 816 ft bgs. A 24-ft stainless-steel well sump extends to 840 ft bgs.

Centralizers were used to center the well screen within the borehole. Based on the location of the well screen, centralizers were installed above, at, and below the screen. The centralizers are located at 693 ft, 792 ft, 804 ft, and 817 ft bgs, respectively. Figure 7.2-1 shows the as-built well casing configuration and indicates the depths of the various well components from ground surface.

7.2.1 Annular Fill Placement

Placement of annular fill consisted of using a 2.5-in OD steel tremie pipe to deliver annular fill to the specified depths. The borehole was backfilled 843 ft (TD) to 826 ft bgs, using 10/20 sand/bentonite chips in a 75:25 mix. The primary filter pack placed across the screened interval consisted of silica sand (10/20) from 826 to 780 ft bgs. Placement of the secondary filter pack consisted of 20/40 silica sand placed above the screened interval from 780 ft to 778 ft bgs. A transition seal consisting of 10/20 sand/bentonite chips in a 50:50 mix was placed above the secondary filter pack from 778 ft to 730 ft bgs. The annulus was then filled to a depth of 77 ft bgs with a bentonite seal consisting of ⅜-in bentonite chips and 10/20 silica sand in a 10:1 mix. Concrete backfill consisted of 2,500 pounds per square inch (psi) concrete with 4 percent bentonite and was placed from 77 ft bgs to the near surface. A total of 13,300 gal of water was used during well construction. The annular fill material used in Well R-4 is summarized in Table 7.2.1-1.



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Project Technical Informa...

Table 7.2.1-1
Annular Fill Materials Used in Well R-4

Material	Amount	Unit[1]	Mix
Backfill and lower most annular fill: 10/20 sand and bentonite	4 sand/1 bentonite	Bag	80:20
Primary Filter Seal: 10/20 sand	50	Bag	-
Secondary Filter Seal: 20/40 sand	2	Bag	-
Transition seal: 10/20 sand and bentonite	17 sand/17 bentonite	Bag	50:50
Bentonite Seal: ⅜-in Chips and 10/20 sand	8.75/56	Supersack/Bag	10:1
Concrete Backfill	2.5	Cubic Yards	2,500 psi concrete with 4% bentonite

[1] Sand bag = 50 lbs ea; bentonite bag = 50 lbs ea; bentonite Supersack = 3,000 lbs ea.

7.3 Piezometer Construction

The two temporary piezometers (designated west and east) were installed in the corehole during Phase I drilling activities. Each piezometer consisted of flush-threaded connecting joints with O-rings of 2-in OD, Schedule 40 polyvinyl chloride (PVC) well casing and a 10-ft section of Schedule 40 PVC 0.010-in slotted screen sections. The west and east piezometers were screened from 125 ft to 115 ft bgs and from 231 ft to 221 ft bgs, respectively. Placement of annular fill was performed by using a 2.5-in OD steel tremie pipe to deliver annular fill to the specified depths.

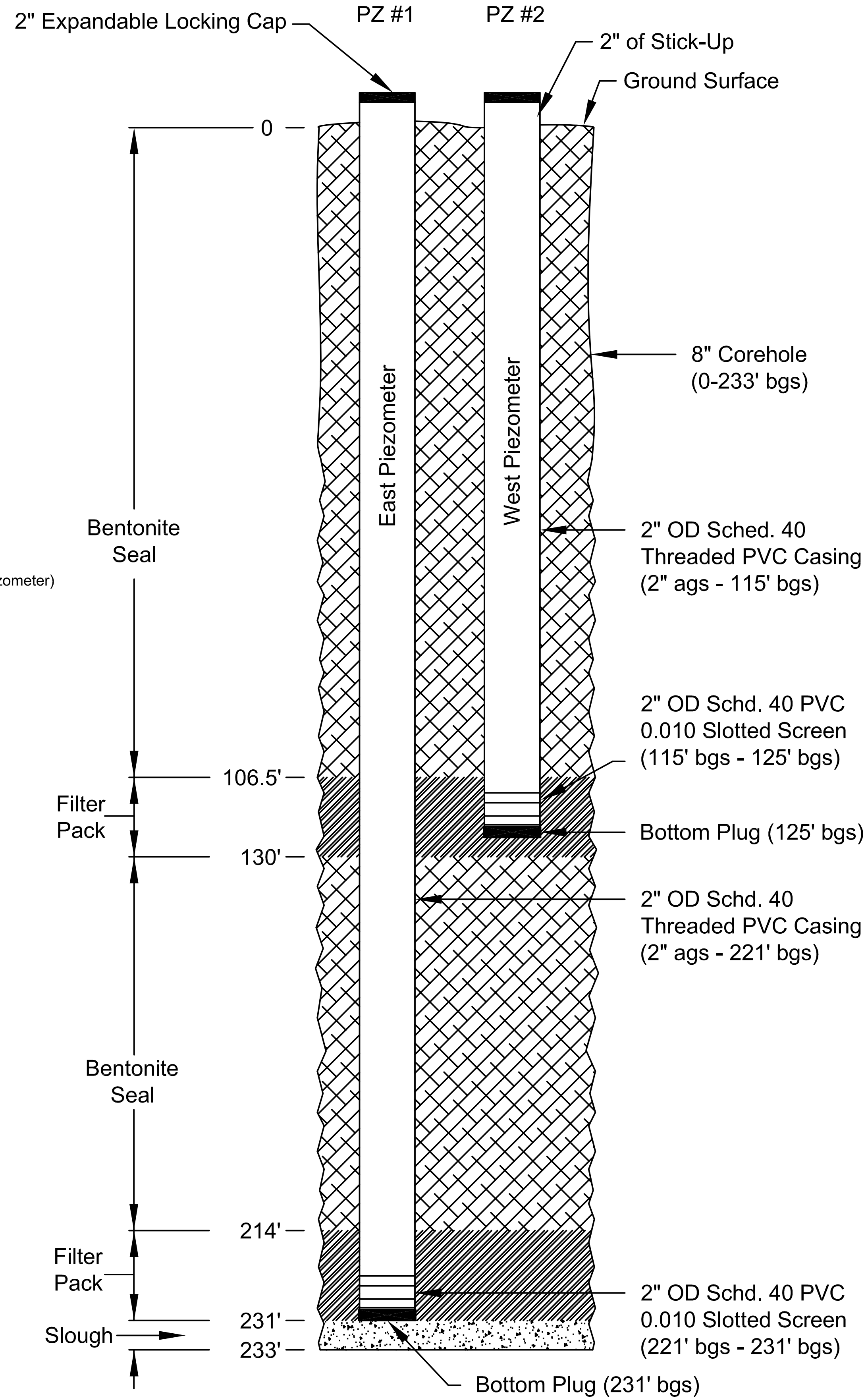
The west piezometer was screened from 115 ft bgs to 125 ft bgs with a filter pack of 10/20 silica sand placed 106.5 to 128 ft bgs. A bentonite seal, hydrated ⅜-in bentonite chips, was placed from 106.5 ft bgs to ground surface.

The east piezometer was screened from 221 ft bgs to 231 ft bgs with a filter pack of 10/20 silica sand placed from 214 ft to 231 ft bgs. A bentonite seal, hydrated ⅜-in bentonite chips, was placed from 128 ft to 214 ft bgs.

An expandable locking cap, compatible to the PVC casing was placed atop each piezometer. Piezometer surface completions were not performed. Figure 7.3-1 shows the as-built piezometer casing configurations and indicates the depths of the various piezometer components from ground surface.

8.0 WELL DEVELOPMENT AND HYDROLOGIC TESTING

Well development activities at Well R-4 were conducted from October 6, 2003 to October 10, 2003. Well development procedures, described below, included well screen swabbing, surging, bailing, and pumping. Hydrologic testing of R-4 was conducted on December 16, 2003 through January 6, 2004. A summary of hydrologic testing conducted at Well R-4 is presented in Section 8.3. A hydrologic report is presented as Appendix D.



Location: At inactive emergency Landing Strip
in Pueblo Canyon; TA-74

Survey Coordinates / Elevations:
- Coordinates: NAD83
- Elevation: NGVD29

Description: Core Hole Piezometer - West
Northing: 1776516.9
Easting: 1639297.4
Elevation: 6577.4

Description: Core Hole Piezometer - East
Northing: 1776516.9
Easting: 1639297.6
Elevation: 6577.34

Corehole Piezometer Completions:
- Casing - 2" OD Sched. 40 PVC threaded
- Number of Screens - One (1) (in each piezometer) 2" OD Sched. 40 PVC 0.010 slotted.
- Screen Interval - West - 115' - 125' bgs
  East - 221' - 231' bgs

LEGEND:

Bentonite Seal
(Bentonite Chips, Hydrated)

Filter Pack
(10-20 Silica Sand)

Slough

Keyed Notes:

1. Completion Date: 09-05-03
2. All depths are below ground surface (bgs)
3. ags: above ground surface
4. Drawing not to scale

KLEINFELDER

Drawn By: C. Landon	Date: January 2005
Project No.: 37151	Filename: Figure 7.3–1.dwg
Scale: Not To Scale	Revision: 1
Reviewed By: F. Schelby	Approved By: A. Kuhn

Schematic Diagram of
East and West Corehole Piezometers Well R-4
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
7.3-1

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8.1 Well Development

Well development in the regional aquifer at Well R-4 was performed in two stages using a Pulstar 12000 development rig. The initial stage consisted of swabbing and surging the screened interval to draw fine sediment from the constructed filter pack, and bailing to remove solid materials from the well. The second stage consisted of lowering a submersible pump into the well and drawing the pump repeatedly across the screened interval. On/off cyclic pumping was performed to remove remaining fines from the filter pack and adjacent formation.

Criteria for well development were based on field water-quality parameters (turbidity, specific conductance, pH, and temperature). To monitor progress during each development stage, samples of water were periodically collected and parameter measurements were recorded. Additionally, samples were collected toward the end of pump development for total organic carbon (TOC) analysis. The concentration of TOC in the groundwater is an indication of the degree to which drilling fluids have been developed from the well. A measurement at or below 2 ppm indicated that drilling fluids were sufficiently removed from the system. Table 8.1-1 presents the water quality parameter data values measured at the completion of each well development task. The primary objective of well development was to remove suspended sediment from the water until turbidity, measured in nephelometric turbidity units (NTU), was less than 5 NTU for three consecutive samples. Similarly, other measured parameters were required to stabilize before terminating development procedures.

Table 8.1-1
Water Removed and Final Water Quality Parameters During R-4 Well Development and Aquifer Testing

		Final Parameters				
Method	**Water Removed (gal.)**	**pH**	**Temperature (°C)**	**Specific Conductance (µS/cm)[a]**	**Turbidity (NTU)**	**Total Organic Carbon (ppm)**
Bailing/swabbing screen	150	8.3	23.3	696	NM[b]	NM
Pumping screen	14,000	7.97	25.2	177	3.1	1.34
Aquifer Testing	42,197	–	–	–	–	–
Total	56,347	–	–	–	–	–

[a] Specific conductance is reported in microsiemens per centimeter (µS/cm).
[b] NM = Not measured.

Initial swabbing of the screened interval was conducted during well construction. This was followed by preliminary bailing from the Well R-4 screened interval and sump to remove bentonite materials, drilling fluids, formation sands, and fines that had been introduced into the well during drilling and installation activities. Bailing procedures were conducted by WDC using a 5-gal capacity stainless-steel bailer. Bailing procedures continued until water clarity improved. Water turbidity was not measured during the bailing process due to equipment malfunction. Bailing was followed by swabbing across the screened interval to enhance filter-pack development. A swabbing tool was lowered into the well and drawn repeatedly across the screen interval for approximately one hour.

Following swabbing, the well was developed for five days using a 10 horsepower (hp) submersible pump. The pump intake was lowered to the screened interval and cycled on at a nominal rate of 9.0 gal per minute (gpm). The pump intake was then drawn across the length of the screened interval. While pumping at Well R-4, water samples were collected at approximately one-hour intervals for parameter measurements. Approximately 14,150 gal of water were withdrawn from the well during development.

Figure 8.1-1 illustrates the effects of pump development on measured field parameters. The graph shows that specific conductance, pH, and temperature were stable during the latter period of pumping and that turbidity values declined consistently to less than 5 NTU. The turbidity spike and corresponding drop in water temperature at the 9,470 gal measurement was from the first sample collected following an overnight shutdown.

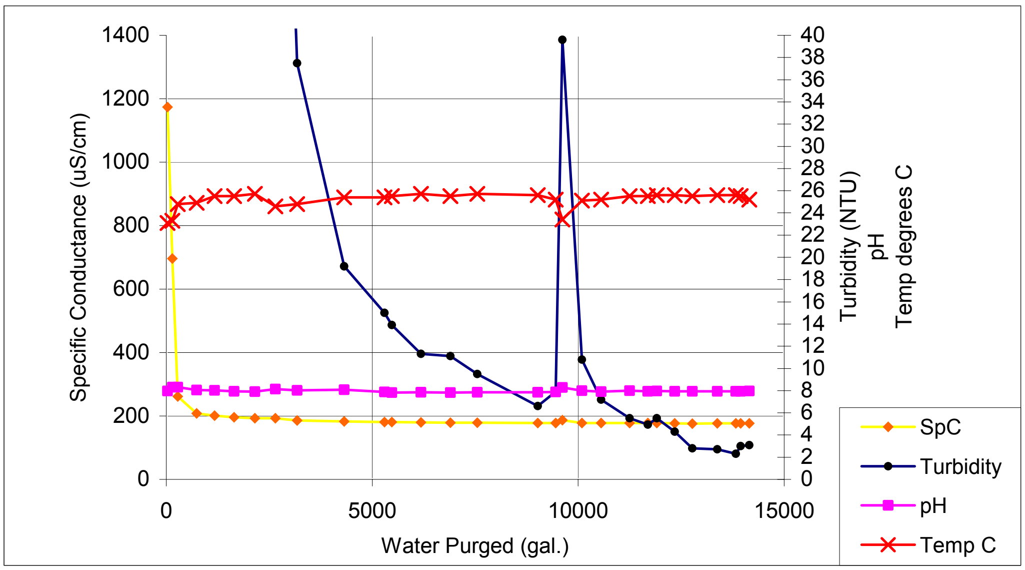

Figure 8.1-1. Effects of Pump Development on Water Quality Parameters at Well R-4

8.2 Hydrologic Testing

Aquifer testing was performed to determine the hydraulic properties of aquifer material at Well R-4. Additionally, barometric pressure monitoring equipment was performance tested during the tests.

Three tests were performed between December 16, 2003 and January 6, 2004. Data from the first two tests were not valid. An improperly manufactured drop pipe that permitted water to leak back into the well during recovery adversely affected the data. After the problem was diagnosed and resolved, a third aquifer test was conducted. A detailed report of aquifer test design and results are included in Appendix D.

Results of the aquifer test indicate that Well R-4 is completed in highly transmissive sediments with a tranmissivity in excess of 100,000 gpd/ft. Hydraulic conductivity values range from 10 gpd/ft2 to 250 gpd/ft2. Casing storage effects that dominate the early drawdown and recovery response make it difficult to accurately estimate the transmissivity and hydraulic conductivity of the aquifer material at Well R-4. However, these tests did provide a lower bound for transmisivity and a reasonable range for hydraulic conductivity.

9.0 WELLHEAD COMPLETION AND SITE RESTORATION

Completion activities include installation of a concrete surface pad and protective bollards surrounding the wellhead; surveying the wellhead locations; and properly disposing of drilling fluids and drill cuttings. Additional activities will include grading the site, backfilling the pit, and re-seeding the area.

9.1 Wellhead Completion

The surface completion for Well R-4 involved pouring a reinforced (2,500 psi) concrete pad, 6-ft wide by 6-ft long by 6-in thick, around the well casing. A brass survey pin was installed in the northwest corner of the pad. A 10.75-in steel casing with locking lid protects the well riser. Four 4-in diameter steel bollards were installed surrounding the pad. The pad was designed to be slightly elevated, with base course graded up around the pad to allow for drainage.

9.2 Geodetic Survey

The location of Well R-4 was determined by geodetic survey using a Leica TCR303 electronic total station. Lynn Engineering and Surveying, Inc. performed the survey. Coordinates and elevations were obtained from LANL Monument #B0006, using a Static Global Positioning System (GPS). Monument #B0006 is located immediately east of the intersection of New Mexico State Road 4, Pajarito Road, and Grand Canyon Drive in White Rock, New Mexico. Control point measurements were provided by Merrick and Co., LANL permanent monument records.

This survey located the brass cap monument at Well R-4 in the concrete pad, the top of the stainless-steel well casing, the top of PVC-casing of the west and east piezometers and the ground surface elevation of the abandoned borehole. Table 9.2-1 summarizes the results of readings conducted for various components of the completed wellhead. The coordinates shown are in New Mexico State Plane Grid Coordinates, Central Zone (North American Datum, 1983 [NAD 83]), expressed in feet. Elevation is expressed in feet above mean sea level relative to the National Geodetic Vertical Datum of 1929 (NGVD 29). The Survey Plat is on file KA's Albuquerque office.

Table 9.2-1
Geodetic Data for Well R-4

Description	Northing(1)	Easting(1)	Elevation(2)
Brass cap in Well R-4 pad	1776530.28	1639287.98	6577.49
Top of stainless-steel casing	1776528.00	1639289.98	6579.46
Piezometer West	1776516.9	1639297.4	6577.35
Piezometer East	1776516.9	1639297.6	6577.34
Abandoned Borehole	1776516.6	1639412.7	6574.46

(1) Measured in ft, relative to the North American Datum, 1983.
(2) Measured in ft above mean sea level relative to the National Geodetic Vertical Datum of 1929.

The location identification number assigned by LANL's Facility for Information Management, Analysis and Display for the R-4 well is 04-22516.

9.3 Dedicated Sampling System Installation

Preparations of bid and specification documents for installation of the permanent sample pump are underway. KA currently anticipates the sampling pump to be installed in Well R-4 by the end of March 2004.

9.4 Site Restoration

On November 17, 2003, a Notice of Intent (NOI) to discharge drilling and development water from the borehole-cuttings containment area at R-4 was forwarded, via e-mail, to NMED Groundwater Quality Bureau staff. Approval to discharge drilling and development water was received via e-mail from the NMED on November 18, 2003. A copy of the e-mail received from the NMED is presented in Appendix E. Water from the borehole-cuttings containment area was land applicated in the area of the general drill site using a 2,000-gal. capacity water truck.

Borehole cuttings were removed from the borehole-cutting containment area and placed on 6-mil polyethylene. These cuttings are currently being contained on-site, awaiting NMED-approval to use in site restoration.

As of February 24, 2004, the following tasks have been performed:

- The polyethylene liner within the borehole-cuttings containment has been removed;
- The borehole cuttings containment area berms have been removed;
- The borehole cuttings containment area has been backfilled and graded;
- The size of the drilling pad has been reduced to approximately 40 ft long by 40 ft wide;
- Safety fencing has been removed.

Silt fencing and straw bales have been left in place to minimize sediment impacts to waterways during rainfall events.

Future site restoration activities include thin spreading of the borehole cuttings and re-seeding of the site. The cuttings will be thin-spread on-site after NMED-approval has been obtained. Site re-seeding will be performed in the spring of 2004 after spreading of cuttings.

Fluids produced during drilling and development were sampled in accordance with the NOI to Discharge, Hydrogeologic Workplan Wells, filed with the New Mexico Environment Department (NMED). A copy of the discharge media analytical results is presented in Appendix E.

10.0 DEVIATIONS FROM THE WELL R-4 SAP

Appendix F compares the actual characterization activities that were performed at Well R-4 with the planned activities described in the "Hydrogeologic Workplan" (LANL 1998, 59599), and the Well R-4 SAP. Highlights are discussed below.

Planned borehole depth – the SAP stated the approximate depth of the well would be 820 ft bgs. The actual depth of the completed borehole was 843 ft bgs based on depth to water observed in the abandoned borehole.

Planned core depth – as stated in the SAP, the target depth of the corehole was 300 ft bgs. This target depth was contingent on encountering perched water within 200 ft of the surface. Perched water was encountered at approximately 110 ft and 215 ft bgs, respectively. The TD of the corehole was 233 ft bgs due to refusal. This depth permitted installation of two piezometers for the purpose of monitoring perched conditions.

Piezometer installation – piezometer installation was not specified in the SAP. Two piezometers were installed in the corehole to monitor perched water conditions. Details about piezometer installation are presented in Section 7.3.

Drilling methods – fluid assisted, open hole, air rotary methods were specified in the SAP. These methods were used while advancing and collecting samples at the abandoned Well R-4 borehole. Mud rotary drilling methods were required to drill the second R-4 borehole.

Number of water samples collected for contaminant analysis – one intermediate perched groundwater sample was collected during drilling instead of the planned three; one water sample was obtained from the regional aquifer.

11.0 ACKNOWLEDGEMENTS

EnviroWorks, Inc. provided site preparation and restoration activities.

WDC Exploration & Wells provided rotary drilling services.

Tetra Tech EM, Inc. provided support for well site geology, sample collection, and hydrologic testing.

Lynn Engineering & Surveying, Inc. provided the final geodetic survey.

E. Tow, R. Lawrence, and P. Schuh of Tetra Tech EM, Inc., Albuquerque, NM; contributed to the preparation of this report.

Schlumberger provided processing and interpretation of borehole geophysical data.

12.0 REFERENCES

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Appendix A

Groundwater Analytical Results

GEOCHEMISTRY OF SAMPLED WATERS

Groundwater samples were collected from both a perched zone within the Puye Formation fanglomerates (110 to 125 ft bgs) and the regional aquifer (792.9 to 816.0 ft bgs) within unassigned older fanglomerates. These samples were analyzed for inorganic chemicals, total organic carbon (TOC), tritium, and other radionuclides. The groundwater sample collected from the piezometer screened in the perched zone was lifted using a bailer, whereas the regional aquifer sample was collected by using a submersible pump at well R-4. Temperature, turbidity, and pH were determined on-site during sampling of the regional aquifer. Both filtered (metals, trace elements, and major cations and anions) and non-filtered (radionuclides, TOC, and stable isotopes) samples were collected for chemical and radiochemical analyses. Aliquots of the samples were filtered through a 0.45-µm Gelman filter. Samples were acidified with analytical-grade HNO_3 to a pH of 2.0 or less for metal, radionuclide, and major cation analyses. Alkalinity was determined at EES-6 using standard titration techniques.

Groundwater samples were analyzed by EES-6 using techniques specified in the US Environmental Protection Agency (EPA) SW-846 manual. Ion chromatography (IC) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The method detection limit (MDL) for perchlorate using IC is 0.002 ppm or mg/L (2 ppb or 2 mg/L). Inductively coupled (argon) plasma emission spectroscopy (ICPES) was used for calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS).

Radionuclide activity in groundwater was determined by direct counting for tritium; alpha spectrometry for americium, plutonium, and uranium isotopes; gas proportional counting for strontium-90; and gamma spectrometry for cesium-137 and other gamma-emitting isotopes. Contract laboratories performing this work were GEL (radionuclides) and the University of Miami (low-level tritium). Perchlorate was also analyzed by GEL using the liquid chromatography/mass spectrometry/mass spectrometry (LC/MS/MS) method. This method is more sensitive than the IC method, having an MDL of 0.000100 mg/L (0.100 mg/L) and a reporting limit (RL) or quantitation limit (QL) of 0.000400 mg/L (0.400 mg/L). Stable isotopes of oxygen (oxygen-18 and oxygen-16, $\delta^{18}O$) and hydrogen (hydrogen and deuterium, δD) were analyzed by Geochron Laboratories (Cambridge, Massachusetts) using isotope ratio mass spectrometry (IRMS). Stable isotopes of nitrogen (nitrogen-15 and nitrogen-14, $\delta^{15}N$) were analyzed by Coastal Science Laboratories, Inc. (Austin, Texas) using IRMS. Analytical results for the stable isotopes are pending for R-4. The precision limits (analytical error) for major ions and trace elements were generally less than ±10% using ICPES and ICPMS.

Results of screening analyses for the groundwater samples collected from the upper Puye Formation (perched zone) and unassigned older fanglomerate (regional aquifer) in R-4 are provided in Tables A.1 and A.2. The water sample collected from the perched zone contains a mixture of native groundwater, containing tritium, and drilling fluid (bentonite mud) based on sodium and sulfate concentrations of 190 and 182 mg/L, respectively. Similar results showing elevated sodium, sulfate, and/or uranium were observed in groundwater samples collected from screen #7 at well R-19 (Longmire 2002a) and from screen #3 at well R-22 (Longmire 2002b).

Table A.1
Hydrochemistry of Perched Groundwater and the Regional Aquifer Samples at Well R-4 (Filtered Samples)

Location	**Corehole**	**Completed Well**
Depth (ft bgs)	**114 to 125**	**792.9 to 816.0**
Geologic Unit	**Upper Puye Formation**	**Lower Puye Formation**
Date Sampled	**09/09/03**	**10/10/03**
Sample No.	**GW04-03-52302**	**GW04-03-52303**
pH	8.13 (Lab)	7.97 (Field)
Temperature (°C)	Not reported	25.2
Specific Conductance (μS/cm)	Not reported	177
Turbidity (NTU)	Piezometer sample	3.1
Alkalinity (ppm $CaCO_3$/L)	176	70.3
Al (ppm)	0.017	0.34
Sb (ppm)	0.002	[0.001], U
As (ppm)	0.0147	0.0011
B (ppm)	0.16	0.024
Ba (ppm)	0.007	0.037
Be (ppm)	[0.001], U	[0.001], U
HCO_3 (ppm)	195	85.8
Br (ppm)	0.10	0.05
Cd (ppm)	[0.001], U	[0.001], U
Ca (ppm)	2.31	16.2
Cl (ppm)	26.4	4.94
ClO_4 (mg/L) (LC/MS/MS)	Not analyzed	Results pending
ClO_4 (ppm) (IC)	[0.004], U	0.0015
Cr (ppm)	0.0039	0.0033
Co (ppm)	[0.001], U	[0.001], U
Cu (ppm)	0.0063	0.0021
F (ppm)	1.57	0.79
Fe (ppm)	[0.01], U	0.18
Pb (ppm)	0.0002	0.0003
Mg (ppm)	0.42	3.42
Mn (ppm)	0.0025	0.0066
Hg (ppm)	0.00009	0.00010
Mo (ppm)	0.12	0.0022
Ni (ppm)	0.0028	[0.001], U
NO_3 (ppm) (as N)	2.08	1.39
NO_2 (ppm) (as N)	0.34	[0.01], U
C_2O_4 (ppm) (oxalate)	[0.01], U	[0.01], U
PO_4 (ppm) (as P)	0.47	[0.01], U
K (ppm)	4.25	2.58
Se (ppm)	0.002	[0.001], U

Table A.1 (Continued)
Hydrochemistry of Perched Groundwater and the Regional Aquifer Samples at Well R-4 (Filtered Samples)

Location	**Corehole**	**Completed Well**
Depth (ft bgs)	**114 to 125**	**792.9 to 816.0**
Geologic Unit	**Upper Puye Formation**	**Lower Puye Formation**
Date Sampled	**09/09/03**	**10/10/03**
Sample No.	**GW04-03-52302**	**GW04-03-52303**
Ag (ppm)	[0.001], U	[0.001], U
Na (ppm)	190	13.2
SiO_2 (ppm)	38.7	85.6
Tl (ppm)	[0.001], U	[0.001], U
U (ppm)	0.026	0.0008
V (ppm)	0.009	0.006
Zn (ppm)	0.020	0.029
TDS (ppm) (calculated)	663	225

Note: U = not detected. Silica concentrations were calculated from measured silicon (ICPES). Bicarbonate concentrations were calculated from measured alkalinity.

Table A.2
Hydrochemistry of Perched Groundwater and the Regional Aquifer Samples at Well R-4 (Non Filtered Samples)

Location	**Corehole**	**Completed Well**
Depth (ft)	**114 to 125**	**792.9 to 816.0**
Geologic Unit	**Upper Puye Formation**	**Lower Puye Formation**
Date Sampled	**09/09/03**	**10/10/03**
Sample No.	**GW04-03-52302**	**GW04-03-52303**
Tritium (pCi/L)	68 ± 16	19.49 ± 0.64
Am-241 (pCi/L)	Not analyzed	[0.0151], U
Cs-137 (pCi/L)	Not analyzed	[0.856], U
Pu-238 (pCi/L)	Not analyzed	[-0.0146], U
Pu-239, 240 (pCi/L)	Not analyzed	[-0.0117], U
Sr-90 (pCi/L)	Not analyzed	[0.102], U
U-234 (pCi/L)	Not analyzed	0.652
U-235 (pCi/L)	Not analyzed	0.0449
U-238 (pCi/L)	Not analyzed	0.352
TOC (ppm)	Not analyzed	1.34 (10/09/03), 4.02 (10/10/03)
$\delta^{15}N$ (‰)	Not analyzed	Results pending
δD (‰)	Not analyzed	Results pending
$\delta^{18}O$ (‰)	Not analyzed	Results pending

Note: U = not detected. ‰ = permil, NTU = nephelometric turbidity unit, and TOC = total organic carbon. Standard deviation is 1 sigma.

Appendix B

Schlumberger Geophysical Report and Montages
(CD on inside back cover)

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1.0 ABSTRACT

This report describes the borehole geophysical logging measurements acquired in characterization well R-4 by Schlumberger, logged in September 2003 prior to well completion. It also presents the processed results from these measurements and discusses their interpretation. The logging suite was acquired from 7 ft to 846 ft below ground surface, when the borehole was open (uncased) below 40 ft, drilled with 12.25 in diameter bit size, and contained 13.375 in outer diameter steel casing above 40 ft.

The primary purpose of the geophysical logging was to characterize the geologic/hydrogeologic section intersected by the well with emphasis on determining regional aquifer groundwater level, perched groundwater zones, moisture content, capacity for flow, and the stratigraphy/mineralogy of geologic units. A secondary purpose of the geophysical logging was to evaluate the borehole conditions such as borehole diameter versus depth, deviation versus depth, and degree of drilling fluid invasion. These objectives were accomplished by measuring, nearly continuously, along the length of the well: (1) total and effective water-filled porosity and pore size distribution, from which an estimate of effective water hydraulic conductivity is made, (2) bulk density (sensitive to total water- plus air-filled porosity), (3) bulk electrical resistivity at multiple depths of investigation, (4) bulk concentrations of a number of important mineral-forming elements, (5) spectral natural gamma ray, including potassium, thorium, and uranium concentrations, (6) bedding orientation and geologic texture, (7) borehole inclination and azimuth, and (8) borehole diameter.

Preliminary results of these measurements were generated in the logging truck at the time the geophysical services were performed and are documented in field logs provided on-site. However, the measurements presented in the field results are not fully corrected for borehole conditions and are provided as separate, individual logs. The field results were reprocessed by Schlumberger to (1) correct and improve the measurements, as best as possible, for borehole formation environmental conditions, (2) perform an integrated analysis of the log measurements so that they are all coherent, and (3) combine the logs in a single presentation, enabling integrated interpretation. The reprocessed log results provide better quantitative property estimates that are consistent for all applicable measurements, as well as estimates of properties that otherwise could not be reliably estimated from the single measurements alone (e.g., total porosity inclusive of all water and air present, water saturation, mineralogy).

The geophysical log measurements from Well R-4 provide good quality results that are consistent with each other through much of the borehole, although the quality of some measurements was degraded across intervals where the borehole contains large washouts. The measurements most affected by the adverse borehole conditions were ones that have a shallow depth of investigation and require close contact to the borehole wall—the bulk density, photoelectric effect, and the porosity measurements. The greatest impact on the log processing was erroneously high estimated air-filled and/or water-filled porosity in the problem zones. Through the integrated analysis and interpretation of all the logs, the individual shortcomings of the specific measurements are reduced. Thus, the integrated log analysis results (e.g. the optimized water-filled porosity log) are the most robust single representation of the geophysical

log results—providing a wealth of valuable high resolution information on the geologic and hydrogeologic environment of the R-4 locale.

Important results from the processed geophysical logs in R-4 include the following:

1. The top of the Regional Aquifer likely lies between 745 ft and 750 ft bgs. The estimated pore volume water saturation is very high below 746 ft to the bottom of the log interval (846 ft) and decreases significantly above this depth. In addition, the water content and porosity are high (30–45% of total rock volume), and there is a consistent amount of moveable water (5–15% of total rock volume). (Note: The water level measured during drilling in the boring was at 732 ft bgs. The water level was measured at 736 ft bgs in the completed well.)
2. The highest measured effective porosity (10–15% of total rock volume) across the section of the log interval that transects the likely top of the Regional Aquifer (746–846 ft) occurs in the zones 800–810 ft and 817–820 ft. Correspondingly, these zones have the highest estimated hydraulic conductivity and production capacity in this interval.
3. The vadose zone (above 746 ft) has highly variable water/moisture content, ranging from 7% of the total rock volume to 38% in sections of the borehole that are not washed out. The borehole contains large washouts above 242 ft, which were full of drilling mud at the time of logging – causing erroneously high water content measurements.
4. Elevated water content (20–35% of total rock volume), moveable water volume (5–20%) and total air plus water porosity (30–50%) occurs in the interval 375–441 ft. The geophysical logs indicate this interval is a porous pumiceous fanglomerate containing zones with high amounts of clay near the bottom. The highest amounts of moveable water occur above these clay layers that are interbedded throughout the 375–441 ft depth interval, suggesting water is accumulating on top of the much lower-permeability clays.
5. Minor or negligible amounts of moveable water occur above 375 ft, although the logs have very high total water content in a number of zones – most of which is bound water likely corresponding to drilling mud measured in washouts.

2.0 INTRODUCTION

Geophysical logging services were performed in characterization well R-4 by Schlumberger in September 2003, prior to initial well completion. The purpose of these services was to acquire in-situ measurements that help characterize the borehole, near-borehole, and abutting geologic formation environment. The primary objective of the geophysical logging was to provide in situ evaluation of formation properties (hydrogeology and geology) intersected by the well. This information was (and is) used by scientists, engineers, and project managers in the Los Alamos Characterization and Monitoring Well Project to design the well completion, better understand subsurface site conditions, and assist in overall decision-making. Standard Operating Procedures for calibration and operation of logging tools are on file at Schlumberger's Farmington, New Mexico office.

The primary geophysical logging services performed by Schlumberger in well R-4 were the:

- Combinable Magnetic Resonance (CMR*) tool to measure the nuclear magnetic resonance response of the formation, which is used to evaluate total and effective water-filled porosity of the shallow formation and to estimate pore size distribution and in situ hydraulic conductivity;
- Compensated Neutron Tool (CNT*) to measure volumetric water content of the formation, which is used to evaluate moist/porous zones;
- Triple detector Litho-Density (TLD*) tool to measure formation bulk density and photoelectric factor, which are used to estimate total porosity and lithology;
- Array Induction Tool, (AIT*) to measure formation electrical resistivity at five depths of investigation, which is used to evaluate drilling fluid invasion into the formation, presence of moist zones far from the borehole wall, and presence of clay-rich zones;
- Formation Micro-Imager (FMI*) tool to measure electrical conductivity images of the borehole wall in fluid-filled open hole and borehole diameter with a two-axis caliper – used for evaluating geologic bedding and fracturing, including strike and dip of these features and fracture apertures, and rock texture;
- General Purpose Inclinometry Tool (GPIT*) to measure borehole deviation and azimuth in openhole – used to evaluate borehole position versus depth and to orient FMI images;
- Natural Gamma Spectroscopy (NGS) tool to measure gross natural gamma and spectral natural gamma ray activity, including potassium, thorium, and uranium concentrations, which are used to evaluate geology/lithology, particularly the amount of clay and potassium-bearing minerals;
- Elemental Capture Spectroscopy (ECS*) tool to measure elemental weight percent concentrations of a number of elements – used to characterize mineralogy and lithology of the formation

In addition, calibrated gross gamma ray (GR) was recorded with every service except the NGS, for the purpose of depth matching the logging runs to each other. Table 2.1 summarizes the geophysical logging runs performed in R-4.

Table 2.1
Geophysical logging services, their combined tool runs and intervals logged, as performed by Schlumberger in borehole R-4

Date of Logging	Borehole Status	Run #	Tool 1	Tool 2	Tool 3	Depth Interval (ft)
27-Sept-2003	Open hole below 40 ft Bit size of 12.25 in. Steel casing above 40 ft. Casing OD of 13.375 in.	1	TLD	CNT		7–846 ft
Same	Same	2	NGS	AIT		10.5–840 ft
Same	Same	3	CMR	ECS	GR	35–846 ft
Same	Same	4	FMI	GPIT	GR	97–840 ft

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A description of these geophysical logging tools can be found on the Schlumberger website (http://www.hub.slb.com/index.cfm?id=id11618).

3.0 METHODOLOGY

This section describes the methods employed by Schlumberger for performed geophysical logging services in Well R-4, including the following stages/tasks:

- Measurement acquisition at the well site
- Quality assessment of logs
- Reprocessing of field data

3.1 Acquisition Procedure

Once the well drilling project team notified Schlumberger that R-4 was ready for geophysical well logging, the Schlumberger district in Farmington, NM, mobilized a wireline logging truck, the appropriate wireline logging tools and associated equipment, and crew to the job site. Upon arriving at the LANL site, the crew completed site entry paperwork and received a site-specific safety briefing.

After arriving at the well site, the crew proceeded to rig up the wireline logging system, including:

1. Parking and stabilizing the logging truck in a position relative to the borehole that is best for performing the surveys;

2. Performing any required environmental protection procedures (e.g., covering the ground with plastic liner, where the tools will be assembled, and around the well) as specified in the work order;

3. Setting up a lower and an upper sheave wheel (the latter attached to, and hanging above, the borehole from the drilling rig/mast truck);

4. Threading the wireline cable through the sheaves; and

5. Attaching the appropriate sonde(s) for the first run to the end of the cable.

Next, pre-logging checks and any required calibrations were performed on the logging sondes and the tool string was lowered into the borehole. If any of the tools required active radioactive sources (in this case a neutron and gamma source for the CNT/ECS and TLD, respectively) just prior to lowering the tool string, the sources were taken out of their carrying shields and placed in the appropriate tool source-holding locations using special source handling tools. The tool string was lowered to the bottom of the borehole and brought up at the appropriate logging speed as measurements were made. At least two logging runs (one main and one repeat) were made with each tool string.

Upon reaching the surface any radioactive sources were removed from the tools and returned to their appropriate storage shields, thus eliminating any radiation hazards. The tool string was cleaned as it was pulled out of the hole.

The second tool string was attached to the cable for another suite of logging runs.

After completion of the surveys, any post-logging measurement checks were performed. Before departure, the engineer printed the field logs (including calibration summaries) for on site distribution and sent the data via satellite to the Schlumberger data archiving center. The Schlumberger data processing center was alerted that the data were ready for post-acquisition processing.

3.2 Log Quality Control and Assessment

Schlumberger has a thorough set of procedures and protocols for ensuring that the geophysical logging measurements are of very high quality. This includes full calibration of tools when they are first built; regular recalibrations and tool measurement/maintenance checks, and real-time monitoring of log quality as measurements are made. Indeed, one of the primary responsibilities of the logging engineer is to ensure, before and during acquisition, that the log measurements meet prescribed quality criteria.

A tool specific base calibration that directly relates the tool response to the physical measurement using the designed measurement principle is performed on all Schlumberger logging tools when first assembled in the engineering production centers. This is accomplished through a combination of computer modeling and controlled measurements in calibration models with known physical parameters.

The base calibration is augmented through regular "master calibrations" for most Schlumberger tools – typically performed every one to six months in local Schlumberger shops (such as Farmington, New Mexico), depending on tool design. Master calibrations consist of controlled measurements using specially designed calibration tanks/jigs and internal calibration devices that are built into the tools. The measurements are used to fine-tune the tool's calibration parameters and to verify that the measurements are valid.

In addition, on every logging job, on-site before and after "calibrations" are executed for most Schlumberger tools directly before/after lowering/removing the tool string from the borehole. For most tools these represent a measurement verification instead of an actual calibration – used to confirm the validity of the measurements directly before acquisition and to ensure that they have not drifted or been corrupted during the logging job.

All Schlumberger logging measurements have a number of associated depth-dependent quality control (QC) logs and flags to assist with identifying and determining the magnitude of log quality problems. These QC logs are monitored in real-time by the logging engineer during acquisition and are used in the post-acquisition processing of the logs to determine the best processing approach for optimizing the overall validity of the property estimates derived from the logs.

Additional information on specific tool calibration procedures can be found on the Schlumberger web page (http://www.hub.slb.com/index.cfm?id=id11618). Though institutionalized national standards (e.g., ASTM) for tool calibration does not exist, Schlumberger has been the leader in development of these procedures. In addition, all wells at LANL have been logged and evaluated by Schlumberger.

3.3 Processing Procedure

After the geophysical logging job was completed in the field and the data archived, the data were downloaded to the Schlumberger processing center. There the data were processed, in the order listed below to (1) correct the measurements for near-wellbore environmental conditions and redo the raw measurement field processing for certain tools using better processing algorithms, (2) depth match and merge the log curves from different logging runs, and (3) model the near-wellbore substrate lithology/mineralogy and pore fluids through integrated log analysis. Separately, the FMI electrical image was processed to produce scaled and normalized high-resolution images that were interpreted to identify geologic features and compute fracture apertures. Afterwards an integrated log montage was built to combine and compile all the processed log results.

Environmental Corrections and Raw Measurement Reprocessing

If required, the field log measurements were processed to correct for conditions in the well, including fluid type (water or air), presence of steel casing, and (to a much lesser extent) pressure and temperature. Basically these environmental corrections entail subtracting from the measurement response the known influences of the set of prescribed borehole conditions. In R-4 the log measurements requiring these corrections are the CNT porosity, TLD density, ECS elemental concentrations, and NGS spectral gamma ray logs.

Two CNT neutron porosity measurements are available – one that measures thermal (slow) neutrons and one that measures epithermal (faster) neutrons. Measurement of epithermal neutrons is required to make neutron porosity measurements in air-filled hole. In water/mud filled hole both the CNT epithermal and thermal neutron measurements are valid, but the thermal neutron porosity has better statistical precision. A version of the CNT that only measures thermal neutrons was used in R-4 since the entire log interval was mud-filled. The thermal neutron porosity measurement was reprocessed for borehole conditions and casing (above 40 ft), although the results were very similar to the field logs. Thus, for further processing and analysis (e.g., ELAN analysis), the reprocessed thermal neutron porosity log was used.

The standard open hole-processing algorithm used for the TLD density measurement is influenced by the steel density in cased hole. A cased hole density algorithm was applied to the raw TLD field measurements to try to eliminate the casing response. While the algorithm can account for the casing per se, it cannot account for air- or water-filled gaps in the annulus between the casing and the formation that cause erroneously low bulk density readings.

The raw ECS elemental yield measurements include the contribution of iron from steel casing and hydrogen from fluid in the borehole. The processing consists of subtracting these unwanted contributions from the raw normalized yields, then performing the normal elemental yields-to-weight fraction processing. The contribution to subtract is a constant baseline amount (or zoned constant values if there are bit/casing size changes), usually determined by comparing the normalized raw yields in zones directly below/above the borehole fluid/casing change. The ECS log in R-4 has a very short cased hole section (five feet), but a casing correction was still applied. The entire ECS logging interval (35–846 ft) was below the well water level because mud was used during drilling. Consequently there was no hydrogen log interval in air-filled hole from which to directly compare to the hydrogen log in the mud/water-filled hole. In this case the hydrogen baseline subtraction was determined by a trial and error comparison of the resulting estimated ECS water content with CNT and TLD porosities to check relative agreement.

The NGS spectral gamma ray data are affected by the material (fluid, air, casing) in the borehole because different types and amounts of these materials have different gamma ray shielding properties; the NGS measures incoming gamma rays emitted by radioactive elements in the formation surrounding the borehole. The processing algorithms try to correct for the damping influence of the borehole material. The NGS logs from R-4 were reprocessed to fully account for the environmental effects of the drilling mud, account for washouts, and for casing above 40 ft.

Depth-Matching

Once the logs were environmentally corrected for the conditions in the wellbore and the raw measurement reprocessing was completed, the logs from different tool runs were depth-matched to each other using the AIT-NGS tool run as the base reference. Gamma ray data were used as the common correlation log measurement for depth-matching the different runs.

Integrated Log Analysis

An integrated log analysis, using as many of the processed logs as possible, was performed to model the near-wellbore substrate lithology/mineralogy and pore fluids. This analysis was performed using the Elemental Log Analysis (ELAN∗) program (Mayer and Sibbit, 1980; Quieren et al, 1986) – a petrophysical interpretation program designed for depth-by-depth quantitative formation evaluation from borehole geophysical logs. ELAN estimates the volumetric fractions of user-defined rock matrix and pore constituents at each depth based on the known log measurement responses to each individual constituent by itself[1]. ELAN requires an a priori specification of the volume components present within the formation—fluids, minerals, and rocks. For each component, the relevant response parameters for each measurement are also required. For example, if one assumes that quartz is a volume component within the formation and the bulk density tool is used, then the bulk density parameter for this mineral is well known to be 2.65 g/cc.

∗Mark of Schlumberger

[1]Mathematically this corresponds to an inverse problem – solving for constituent volume fractions from an (over)determined system of equations relating the measured log results to combinations of the tool measurement response to individual constituents

The logging tool measurements, volume components, and measurement response parameters used in the ELAN analysis for R-4 are provided in Table 3.1. The final results of the analysis – an optimized mineral-fluid volume model – are shown on the integrated log montage (see Appendix D), 3rd track from the right (inclusive of the depth track). To make best use of all the measurement data and to perform the analysis across as much of the well interval as possible (7–846 ft.), as many as possible of the processed logs were included in the analysis, with less weighting applied to less robust logs. Not all the tool measurements shown in Table 3.1 are used for the entire interval analyzed, as not all the measurements are available, or of good quality, across certain sections of the borehole. To accommodate fewer tool measurements certain model constituents are removed from the analysis in some intervals. Most notably, within the cased interval (above 40 ft) many of the minerals had to be removed from the model due to the absence of many of the logs.

The ELAN analysis was performed with as few constraints or prior assumptions as possible. A considerable effort was made to choose a set of minerals or mineral types for the model that is representative of Los Alamos area's geology and it's volcanic origins. No prior assumption is made about water saturation—where the boundary between saturated and unsaturated zones lies (e.g. the depth to the top of the regional aquifer or perched zones). Thus, the presence and amount of air in the pore space is unconstrained. Total porosity and water-filled porosity are also left unconstrained throughout the analysis interval. Thus, interpretations should be made from the ELAN results with the understanding that the mineral-fluid model represents a mathematically optimized solution that is not necessarily a physically accurate representation of the native geologic formation. Within this context, the ELAN model is a robust estimate of the bulk mineral-fluid composition that accounts for the combined response from all the geophysical measurements.

4.0 RESULTS

The final log results from the borehole geophysical logging performed by Schlumberger in R-4 have been processed, if required, to correct for the well environment and depth-match the logs from different tool runs in the well. Additional logs were generated from integrated analysis of processed measured logs, providing valuable estimates of key geologic and hydrologic properties. In the following description of the results, an attempt is made to organize the discussion based on the evaluation needs addressed by the logs instead of describing each log independently.

The log results are presented as continuous curves of the processed measurement versus depth and are displayed as (1) summary log displays for selected directly related sets of measurements (see Figures 4.1, 4.2, 4.3) and (2) an integrated log montage that contains all the final log curves, on depth and side by side (see Appendix D). The summary log displays address specific characterization needs, such as moisture content and water saturation. The purpose of the integrated log montage is to present, side by side, all the salient reprocessed logs and log-derived models, depth-matched to each other, so that correlations and relationships between the logs can be identified.

Important results from the processed geophysical logs in R-4 are described below.

Well Water Level

R-4 was almost entirely full of drilling mud at the time of logging and, thus, a natural static water level in the borehole could not be measured. Most or all of the four logging runs were within mud-filled hole. The first logging run (TLD-CNT-GR) appears to reach the top of mud-filled hole at 9 ft below ground surface, based on a sharp drop in the neutron porosity log to below zero (in air-filled the neutron porosity measurement becomes invalid and reads less than zero). Several hours later, the second logging run (AIT-NGT) appears to reach the top of the mud column at 18 ft, based on an increase in the borehole fluid resistivity measurement. Measurements in the third and fourth logging runs were stopped below or near the bottom of casing and don't appear to reach the top of the mud column. This suggests the fluid level was dropping during the logging, although it is possible the borehole fluid resistivity is reacting to something other than fluid level.

Regional Aquifer

The processed log results suggest that R-4 penetrates the regional aquifer below approximately 746 ft. The estimated pore volume water saturation (fraction of the total pore volume containing water) is consistently very high (85–100%) from 746 ft to the bottom of the log interval (846 ft). In addition, the water content and porosity are high (30–45% of total rock volume), and there is a consistent amount of estimated moveable water (effective water-filled porosity) across the interval (5–15% of total rock volume). The exact top depth of the regional aquifer is difficult to pinpoint, but the log results strongly suggest that it resides between 745 ft and 750 ft below ground surface. However, the static water level was measured at 736 ft bgs in the completed well.

A steady, moderate level of effective porosity and, thus, water flow capacity is estimated from the processed log results in the interval 746–826 ft (bottom of the CMR log interval – the logging tool that measures moveable water). The highest effective porosity across this interval (10–15% of total rock volume) occurs in the zones 800–810 ft and 817–820 ft. The effective porosity at the bottom of the well (826–846 ft) could not be estimated because this depth interval is below the 10 west reading of the CMR tool measurement.

Table 3.1
Tool Measurements, Volumes and
Respective Parameters Used in the R-4 ELAN Analysis

Volume / Tool Measurement	Air	Capillary Bound Water	Water	Hornblende	Hypersthene	Labradorite	Silica Glass	Heavy Mafic Minerals	Augite	Montmorillinite	Pyrite	Orthoclase	Quartz
Bulk density (g/cc)	–0.19	1.00	1.00	3.11	3.55	2.65	2.2	4.0	3.08	2.02	4.99	2.58	2.64
Epithermal neutron porosity (ft^3/ ft^3)	-0.02	1.00	1.00	0.05	0.01	-0.01	0.0	0.02	-0.01	0.6	0.17	-0.01	0.0
Thermal neutron porosity (ft^3/ ft^3)	–0.05	1.00	1.00	0.06	0.04	-0.01	0.0	0.07	0.02	0.65	0.01	-0.01	0.0
Volumetric photoelectric effect	0	0	0.40	12	20.2	7	4.2	65.00	23.8	4.4	82.1	7.3	4.8
Total CMR water-filled porosity (ft^3/ ft^3)	0	1.0	1.0	0	0	0	0	0	0	0.425	0	0	0
CMR free fluid volume (ft^3/ ft^3)	0	0	1.0	0	0	0	0	0	0	0	0	0	0
Resistivity (ohm-m)	Very high	35	35	Very high	Very high	Very high	Very high	Very high	Very high	1.23	Very high	Very high	Very high
Dry weight silicon (lbf / lbf)	0.0	0.0	0.0	0.21	0.24	0.24	0.47	0.18	0.23	0.26	0	0.3	0.47
Dry weight calcium (lbf / lbf)	0.0	0.0	0.0	0.09	0.0	0.09	0.0	0.0	0.10	0.01	0.0	0.0	0.0
Dry weight iron (lbf / lbf)	0.0	0.0	0.0	0.07	0.20	0.0	0.0	0.22	0.11	0.02	0.47	0.0	0.0
Dry weight sulfur (lbf / lbf)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.53	0.0	0.0
Dry weight titanium (lbf / lbf)	0.0	0.0	0.0	0.005	0.01	0.0	0.0	0.0	0.048	0.0	0.0	0.0	0.0
Dry weight aluminum (lbf / lbf)	0.0	0.0	0.0	0.07	0.0	0.16	0.0	0.0	0.02	0.11	0.0	0.10	0.0
Wet weight potassium (lbf / lbf)	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.003	0.005	0.0	0.102	0.0
Weight water (lbf / lbf)	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.0	0.0	0.0
Wet weight thorium (ppm)	0.0	0.0	0.0	50	25	3	2	4	20	24	0	5.5	2
Clay bound water volume (ft^3/ ft^3)	0	0	0	0	0	0	0	0	0	0.425	0	0	0

Vadose Zone Perched Water

The processed logs indicate highly variable water/moisture content across the vadose zone depth section (above 746 ft), ranging from 7% of the total rock volume to greater than 60% in large washouts (see Figure 4.1). This variance is reduced to 7–38% moisture content if the log results from the washed out sections of the borehole are excluded.

There is a notable step decrease in the total water volume fraction moving uphole across the likely top of the Regional Aquifer (846 ft) – averaging mostly between 10 – 20% up to 442 ft. In the zone 693–700 ft there is a sharp, unrealistically high spike in the estimated water content (peaking at more than 80%) – caused by a large washout. A similar 40% water content peak occurs at 712 ft where there is a smaller washout. Also at 582 ft and 594 ft there are anomalous spikes of 40% water content that appear to be associated with thin clay layers, as predicted by the ELAN integrated log analysis, and, thus, are likely mostly clay-bound water.

Elevated water content (20–35% of total rock volume), moveable water volume (5–20% of total volume) and total air plus water porosity (30–50% of total volume) occurs in the interval 375–441 ft. This interval does not contain significant washouts, indicating the log measurements are representative of the near borehole formation. Two high clay content zones (greater than 20% dry weight clay) are predicted from the ELAN analysis in this interval: 419–424 ft and 428–436 ft. As would be expected, the clay zones contain less moveable water than the surrounding section. The highest amounts of moveable water occur above these clay layers, suggesting water is accumulating on top of the much lower permeability clays. Based on the ELAN analysis and the FMI electrical image this interval appears to be a high porosity volcanic pumice beds. It is possible that most or all of the measured water in the near borehole formation was introduced by the mud rotary drilling process through invasion of the drilling fluids into the highly porous, permeable pumice beds. However, pure mud invasion would result in a mostly bound water CMR measurement, whereas this interval contains significant amounts of moveable water. The formation and mud cake that forms on the borehole wall also can act as a filter that segregates out the mud clay particles as it invades the formation.

Above 375 ft the processed logs indicate minor or negligible amounts of moveable water, although the logs have very high total water content in a number of zones – most of which is bound water. The interval 200–242 ft contains erroneously high water content and total porosity (60–90%), the result of an enormous borehole washout across the entire interval. The fact that all this water was measured as bound water by the CMR corroborates that the logs are directly measuring drilling mud and not formation water. A similar unrealistically high porosity log anomaly occurs in the interval 39–52 ft, directly below the casing – again resulting from borehole washouts.

Geology

The processed geophysical log results clearly delineate the geologic material intersected by R-4 below the casing (40–846 ft below ground surface), although the results are significantly degraded in zones with severe washouts. The generalized geologic stratigraphy observed from the logs across this interval is as follows (depth below ground surface):

- 40–50 ft: Washed out zone – characterized by unrealistically high porosity (60–90% of total rock volume), difficult to interpret mineralogy and lithology, and apparently high clay content (30–40% dry weight)
- 50–200 ft: Clay-rich dacitic sediments – characterized by high total porosity (30–50% of total rock volume), high potassium feldspar content (~25–35% dry weight), moderate quartz/silica glass content (15–30%), small to moderate amounts of plagioclase (2–20%), a mix of plagioclase-hypersthene-augite-hornblende-mafics (20–35% total), and variable amounts of clay throughout as high as 30% (at 137 ft below ground surface)
- 200–242 ft: Washed out zone – characterized by unrealistically high total porosity (60–90% of total rock volume), difficult to interpret mineralogy and lithology, and apparently high potassium feldspar content (30–40% dry weight)
- 242–375 ft: Volcanic-source fanglomerates – characterized by moderate total porosity (30% of total rock volume), high potassium feldspar content (~25–35% dry weight), moderate quartz/silica glass content (15–30%), small to moderate amounts of plagioclase (2–25%), a mix of plagioclase-hypersthene-augite-hornblende-mafics (30–50% total), and scattered variable amounts of clay as high as 27% (at 297 ft below ground surface)
- 375–413 ft: Volcanic-source fanglomerates – characterized by high total porosity (40–50% of total rock volume), high quartz/silica glass content (~40% dry weight), high potassium feldspar content (~40%), and minor amounts of clay (0–10%)
- 413–442 ft: Volcanic-source fanglomerates – characterized by high total porosity (37–42% of total rock volume), high quartz/silica glass content (20–45% dry weight), high potassium feldspar content (30–40%), and clay-rich beds (as high as 40%) at 419–423 ft and 428–436 ft
- 442–578 ft: Low porosity, clay-rich fanglomerate – characterized by relatively low total porosity (18–27% of total rock volume), moderately high mineral contents of quartz/silica glass and potassium feldspar (individually 20–30% dry weight), and consistent moderate amounts of clay throughout (10–28%)
- 578–604 ft: High porosity, clay-rich fanglomerate – characterized by relatively high total porosity (32–50% of total rock volume), moderately high mineral contents of plagioclase and potassium feldspar (individually 20–30% dry weight), low to moderate amounts of quartz/silica glass (5–15%), and consistent moderate to high amounts of clay throughout (15–48%) with three distinct clay beds (578–584 ft, 592–596 ft, and 600–604 ft)
- 604–778 ft: Heterogeneous, moderate porosity fanglomerate – characterized by moderate total porosity (~30% of total rock volume), moderately high mineral contents of plagioclase and potassium feldspar (individually 20–30% dry weight), low to moderate amounts of quartz/silica glass (5–20%), and consistent minor amounts of clay throughout (5–30%)
- 778–836 ft: Heterogeneous, high porosity fanglomerate – characterized by high total porosity (35–45% of total rock volume), moderately high mineral contents of plagioclase and potassium feldspar (individually 20–30% dry weight), low to moderate amounts of quartz/silica glass (5–20%), and variable minor amounts of clay (0–22%)

4.1 Summary Logs

Three summary log displays have been created:

- Porosity summary to highlight hydrologic information obtained from the log results (Figure 4.1)
- Density and clay content summary to highlight the geologic rock matrix information obtained from the log results (Figure 4.2)
- Spectral natural gamma ray summary to highlight the geologic stratigraphy and correlation information obtained from the log results (Figure 4.3)

4.2 Integrated Log Montage

This section summarizes the integrated geophysical log montage for R-4. The montage is provided as a CD inside the back cover of this report. A description of each log curve in the montage follows—organized under the heading of each track, starting from track 1 on the left-hand side of the montage. Note that the descriptions in this section focus on what the curves are and how they are displayed; the specific characteristics and interpretations of the R-4 geophysical logs are provided in the previous section.

Track 1–Depth

The first track on the left contains the depth below ground surface in units of feet, as measured by the geophysical logging system during the AIT logging run. All the geophysical logs are depth-matched to the spectral gross gamma measurement run with the AIT.

Track 2–Basic Logs

The second track on the left (inclusive of the depth track) presents basic curves:

- Gamma ray (thick black), recorded in API units and displayed on a scale of 0 to 250 API units;
- Two calipers from the FMI (thin dotted and dashed pink) and one from the TLD (thin solid pink) with bit size as a reference (dashed-dotted black) to show washout (pink shading), recorded as hole diameter in inches and displayed on a scale of 11 to 21 in.;
- Spontaneous potential or SP (dashed red – valid only below the borehole water level), recorded in millivolts and displayed on a relative scale;
- Bulk chlorinity (dashed green with green shading), recorded in parts per thousand (ppk) and displayed on a scale of 5 to 0 ppk (left to right);
- Borehole deviation displayed as a tadpole every ten feet (light blue dots and connected line segments) – the "head" marks the angular deviation from vertical at that particular depth, on a scale of zero to 5 degrees, and the "tail" shows the azimuth of the deviation, true north represented by the tail facing straight towards the top of the page.
- Two gamma ray curves from the NGS are presented:

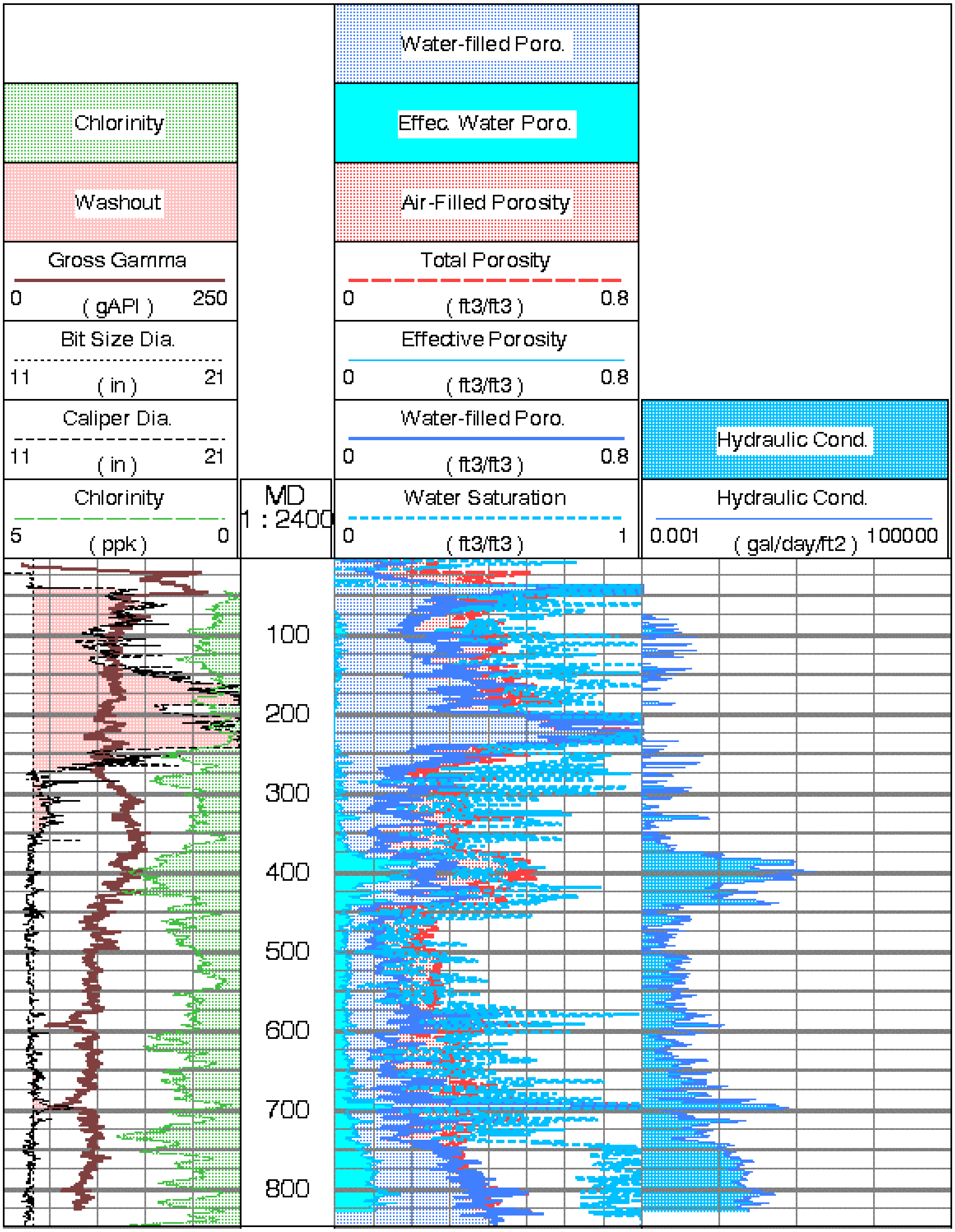

Figure 4.1. Summary porosity logs in R-4 borehole from processed geophysical logs, interval 6–846 ft, with caliper, gross gamma, apparent chlorinity, and water saturation logs. Porosity and water saturation logs are derived from the ELAN integrated log analysis.

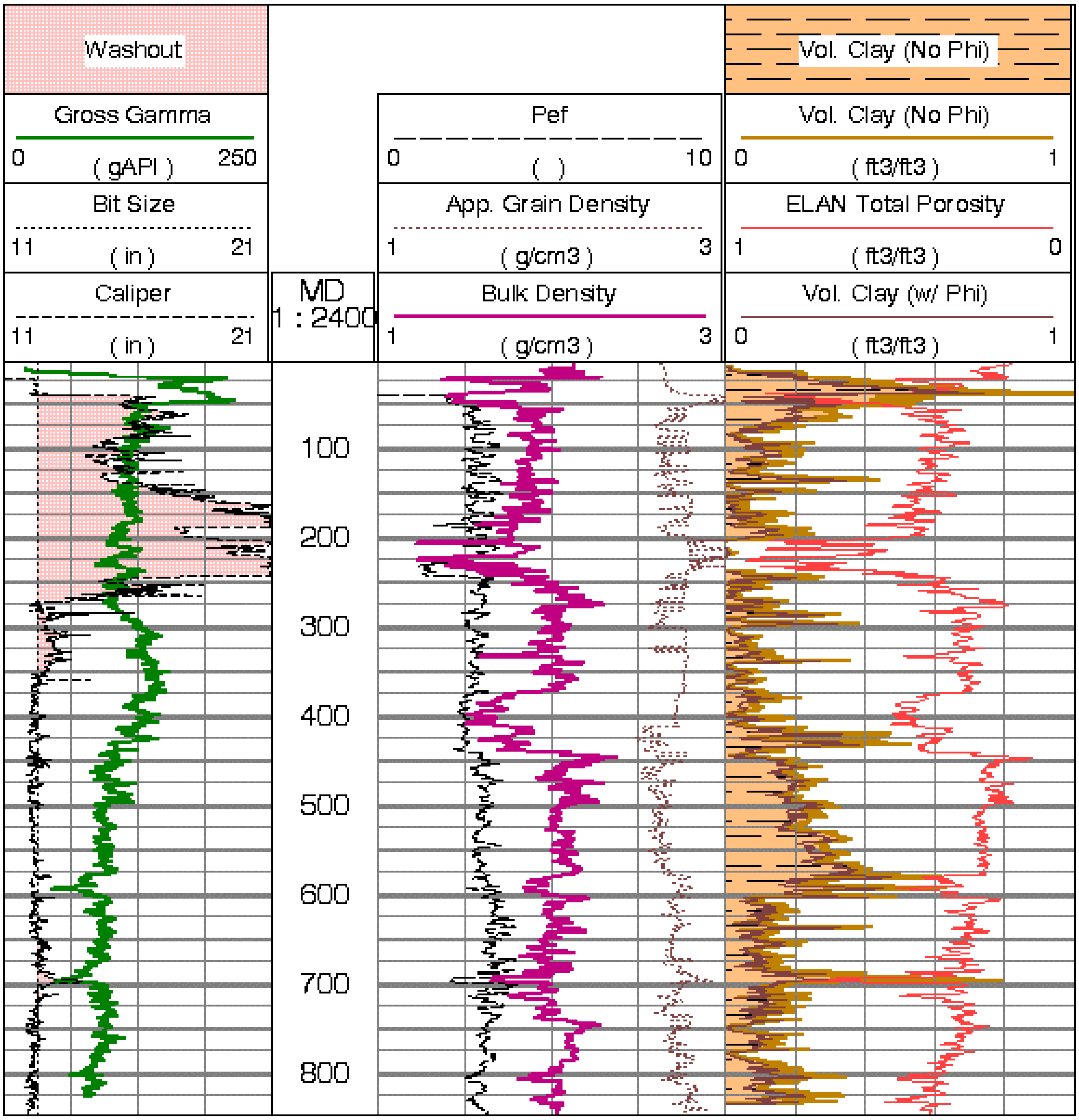

Figure 4.2. Summary bulk density and volume clay logs in R-4 borehole from processed geophysical logs, interval 6–846 ft. Also shown– caliper, gross gamma, apparent grain density, and total porosity logs.

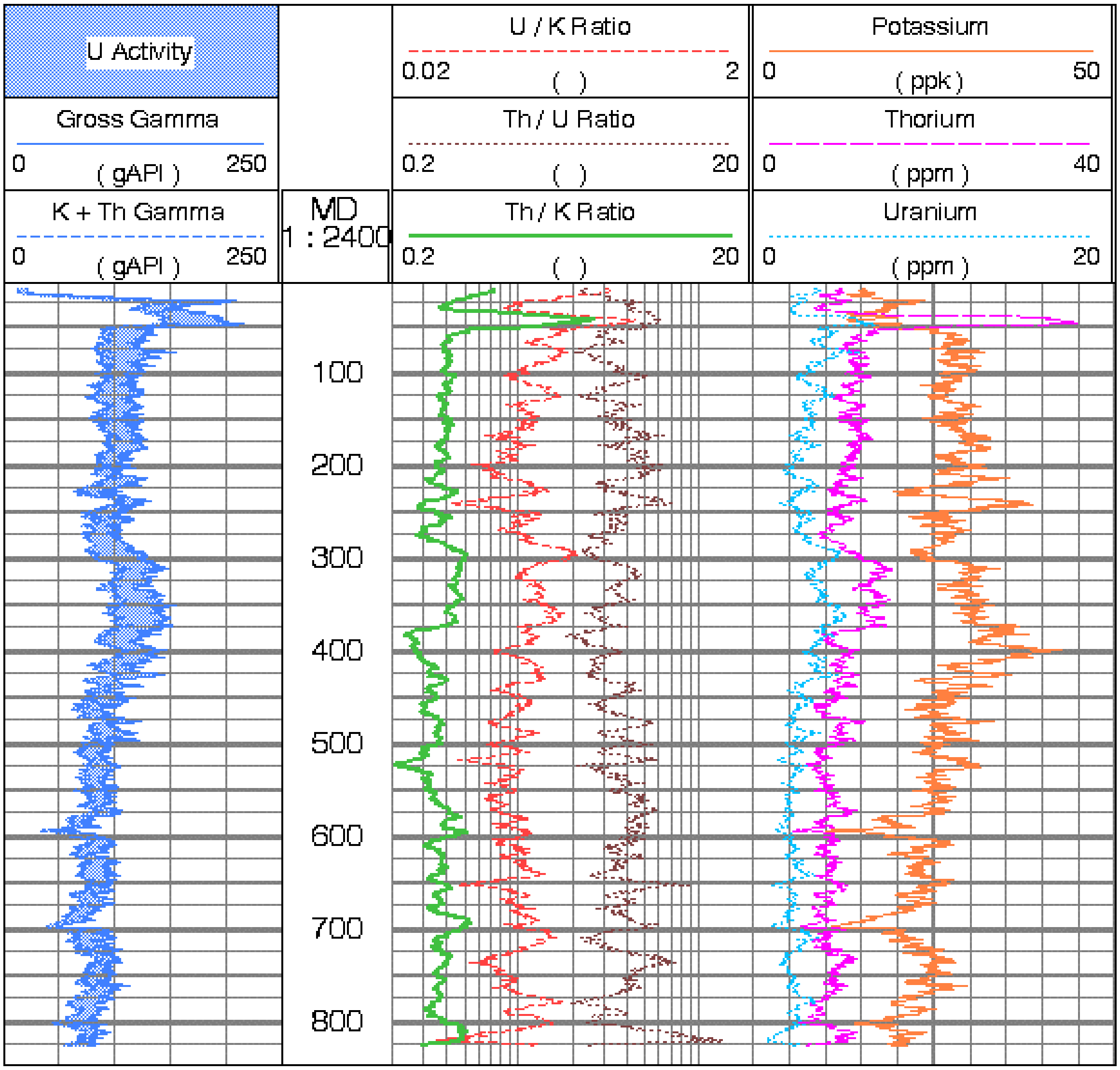

Figure 4.3. Summary spectral natural gamma ray logs from R-4 borehole, interval 6–827 ft

- Total gross gamma (thick solid black curve) and
- Gross gamma minus the contribution of uranium (dashed black).

Track 3–Resistivity

The third track displays the resistivity measurements from the AIT, spanning most of the open hole section. All the resistivity logs are recorded in units of ohmmeters and displayed on a logarithmic scale of 2 to 2000 ohm-m.

Six electrical resistivity logs from the AIT are displayed:

- Borehole fluid resistivity (solid orange curve)–only valid in water-filled hole
- Bulk electrical resistivity at five median depths of investigation–10 in. (black solid), 20 in. (long-dashed blue), 30 in. (short-dashed red), 60 in. (dashed-dotted green), and 90 in. (solid purple)–each having a two-foot vertical resolution.

The area between the 10 in. and 90 in. resistivity curves, representing radial variations in bulk resistivity (potentially from invasion of drilling fluids), is shaded:

- blue when the 10 in. resistivity is greater than the 90 in. resistivity (labeled “resistive invasive”) and
- yellow when the 90 in. resistivity is greater than the 10 in. resistivity (labeled “conductive invasive”).

A high vertical resolution (~8 in.), shallow-reading (~2 in.) micro-resistivity log from the MCFL is also displayed in this track (solid pink curve).

Track 4–Porosity

The fourth track displays the primary porosity log results. All the porosity logs are recorded in units of volumetric fraction and displayed on a linear scale of 0.75 (left side) to negative 0.1 (right side). Specifically, these logs consist of

- CNT air-filled epithermal neutron porosity (solid sky blue curve)–epithermal neutron porosity processed for air-filled hole and, thus, valid (and visible) only in the air-filled borehole (above 833 ft);
- CNT water-filled thermal neutron porosity (solid sky blue curve)–thermal neutron porosity valid only in the water-filled borehole;
- CMR total water-filled porosity (solid black);
- CMR effective water-filled porosity (dashed green);
- CMR bound water porosity (light blue area shading)–representing by the area between the CMR total and effective water-filled porosities;

- Total porosity derived from bulk density and neutron porosity using 2.65 g/cc grain density (thick long dashed red), 2.25 g/cc (thin dashed red), and 3.05 g/cc (thin dotted red)–with red shading between the 2.25 g/cc and 3.05 g/cc curves; and
- ELAN total water and air-filled porosity (dashed-dotted cyan)–derived from the ELAN integrated analysis of all log curves to estimate optimized matrix and pore volume constituents.

Track 5–Density

The fifth track displays the:

- bulk density (thick solid maroon curve) on a scale of 1 to 3 grams per cubic centimeter (g/cc);
- Pe (long-dashed black curve) on a scale of 0 to 10 non-dimensional units;
- density correction (dashed orange curve) on a scale of -0.75 to 0.25 g/cc; and
- apparent grain density (dashed-dotted brown curve), derived from the ELAN analysis, on a scale of 2 to 4 g/cc.

Grey area shading is shown where the Pe increases above 3 (indicating the presence of heavy, possibly mafic, minerals) and orange shading is shown where the density correction is greater than the absolute value of 0.25 (indicating the density processing algorithm had to perform a major correction to the bulk density calculation).

Track 6–NGS Spectral Gamma

The sixth track from the left displays the spectral components of the NGS measurement results as wet weight concentrations:

- potassium (solid green curve) in units of parts per thousand (ppk) and on a scale of -50 to 50 ppk;
- thorium (dashed brown) in units of parts per million (ppm) and on a scale of 50 to -50 ppm; and
- uranium (dotted blue) in units of parts per million (ppm) and on a scale of 20 to 0 ppm.

Track 7–CMR Porosity

Track 7 displays various CMR water-filled porosities along with measurement quality flags–valid only in the open hole section. The porosity and measurement quality logs are presented on a scale of 0.5 to zero volume fraction and discrete blocks originating from the left side, respectively. Specifically, the CMR logs shown in this track are:

- Total water-filled porosity (solid black curve)–representing the total water volume fraction measured by the CMR;

- Three millisecond (ms) porosity (short-dashed brown)–representing the water volume fraction corresponding to the portion of the CMR measured T2 distribution that is above 3 ms, a cutoff that is considered to be representative of the break between clay-bound water (less than 3 ms) and all other types of water (greater than 3 ms);
- Effective water-filled, or free fluid, porosity (solid pink)–representing the water volume fraction that is moveable (can flow), based on a 33 ms T2 distribution cutoff that is considered representative of the break between bound water (less than 33 ms) and moveable water (greater than 33 ms) in clastic rocks;
- Clay-bound water (brown area shading between total and 3 ms porosity logs)–representing the water volume fraction that is bound within clays;
- Capillary-bound water (pink area shading between 3 ms and effective porosity logs)–representing the water volume fraction that is bound within matrix pores by capillary forces;
- CMR wait-time flag (red area shading)–activates when there is significant measurement response at late T2 times, corresponding to large amounts of completely free ("bathtub") water and often associated with washouts or very large pores;
- CMR measurement noise flag (yellow and orange area shading)–activates when there is potentially detrimental amounts of measurement noise detected by the tool, at moderate (yellow) and high (orange) levels.

Track 8–Pore Size Distribution

Track 8 displays the water-filled pore size distribution as determined by the CMR–shown as binned water-filled porosities and valid only in the open hole section. The binned porosity logs are presented on a scale of 0.5 to zero volume fraction with colored area shading corresponding to the different bins:

- Clay-bound water–brown area shading;
- Micro pore and small pore water (the sum comprising capillary-bound water)–gray and blue area shading, respectively;
- Medium pore, large pore, and late decay (the sum comprising effective water-filled porosity)–yellow, red, and green area shading, respectively.

Track 9–CMR T2 Distribution (Waveforms)

The CMR T2 distribution is displayed in Track 9 as green waveform traces at discrete depths. The horizontal axis, corresponding to relaxation time in milliseconds, is on a logarithmic scale from 0.3 to 3000 ms. Also plotted are the:

- T2 logarithmic mean (solid blue curve) and
- T2 cutoff time used for differentiating between bound and free water (solid red line)–a constant 33 ms in this case.

Track 10–CMR T2 Distribution (Heated Amplitude)

Track 10 displays the T2 distribution in another way–on a heated color scale where progressively "hotter" color (green to yellow to red) corresponds to increasing T2 amplitude. The remaining aspects of the display are the same as in Track 9, except that the T2 logarithmic mean is shown as a solid white curve and the T2 cutoff is not displayed.

Track 11–CMR Hydraulic Conductivity

Track 11 displays several estimates of hydraulic conductivity (K) from the CMR measurements, valid only in the open hole section, as well as one derived from the ELAN analysis, presented on a logarithmic scale of 10-4 to 106 gallons per day per feet squared (gal/day/ft^2):

- A K versus depth estimate derived from using the SDR permeability equation, converted to hydraulic conductivity (dashed purple curve);
- A K versus depth estimate derived from using the Timur-Coates permeability equation, converted to hydraulic conductivity (solid blue curve); and
- An intrinsic K versus depth estimate (assuming full saturation) derived from the ELAN analysis, converted to hydraulic conductivity (dotted cyan).

Track 12–FMI Image (Dynamic Normalization)

Track 12 displays the FMI image, processed with dynamic normalization so that small-scale electrical resistivity features are amplified in the image. (With dynamic normalization the range of electrical resistivity amplitudes – colors in the image – is normalized across a small moving depth window.) The image is fully oriented and corresponds to the inside of the borehole wall unwrapped, such that the left-hand side represents true north, half-way across the image is south, and the right-hand side is north again. The four color tracks in the image correspond to portions of the borehole wall contacted by the four FMI caliper pads; the blank space in between is the portion of the borehole wall not covered by the pads.

Also displayed are the interpreted bed boundaries (thin blue sinusoids).

Track 13–FMI Bedding and Fractures

Track 13 displays the interpreted bed boundaries and fractures picked from the FMI image, shown in two ways:

- Individually as blue (bed boundary) tadpoles at the depths the bedding plane or fracture crosses the midpoint of the borehole – where the "heads" (circles) represent the dip angle and the "tails" (line segments) represent the true dip azimuth (direction the bed is dipping towards);
- Summed as dip azimuth rose histograms (green colored fan plots for bed boundaries) – where the number of bed boundaries having a dip direction within a particular sector are summed, thus highlighting the predominant dip directions.

Track 14–FMI Image (Static Normalization)

Track 14 displays the FMI image again, but in a different way – processed with static normalization to highlight larger scale features and trends. (With static normalization the range of electrical resistivity amplitudes – colors in the image – is normalized across the entire length of the log interval.)

Track 15–High Resolution Porosity

Track 15 displays the resolution thermal neutron porosity log (solid blue) and the high resolution density porosity (solid red), the latter computed assuming a matrix grain density of 2.65 g/cc. Both these logs have an 8 in depth resolution. Where the density porosity is greater than the neutron porosity the area between the two logs is shaded yellow. The yellow shading is an indication of air in the pore space (less than 100% water saturation).

Tracks 16 to 20–Geochemical Elemental Measurements

The narrow tracks 16 to 20 present the geochemical measurements iron (Fe) and silicon (Si), sulfur (S) and calcium (Ca), potassium (K) and estimated aluminum (Al), titanium (Ti) and gadolinium (Gd), and hydrogen (H) and bulk chlorinity (Cl) —from left to right respectively, in units of dry matrix weight fraction (except H wet weight fraction, Cl and K in ppk).

Track 21–ELAN Mineralogy Model Results (Dry Weight Fraction)

Track 21 displays the results from the ELAN integrated log analysis (the matrix portion)–presented as dry weight fraction of mineral types chosen in the model:

- Montmorillonite clay (brown/tan)
- Quartz (yellow with small black dots)
- Silica glass (orange)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or other plagioclase feldspar (pink)
- Hypersthene (purple)
- Hornblende (forest green)
- Augite (maroon)
- Heavy mafic/ultramafic minerals, such as magnetite or olivine (dark green)
- Pyrite (cross-hatched red).

Track 22–ELAN Mineralogy-Pore Space Model Results (Wet Volume Fraction)

Track 22 displays the results from the ELAN integrated log analysis–presented as wet mineral and pore fluid volume fractions:

- Montmorillonite clay (brown/tan)
- Clay-bound water (checkered gray-black)
- Quartz (yellow with small black dots)
- Silica glass (yellow with large black dots)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or other plagioclase feldspar (pink)
- Pyrite (tan with large black squares).
- Hypersthene (purple)
- Hornblende (forest green)
- Augite (maroon)
- Heavy mafic minerals, such as magnetite (dark army green)
- Air (red)
- Moveable water (white)
- Capillary-bound water (light blue).

Track 23–Summary Logs

Track 23, the second track from the right, displays several summary logs that describe the fluid and air-filled volume measured by the geophysical tools, including water saturation:

- Optimized estimate of total volume fraction water from the ELAN analysis (solid dark blue curve and area shading);
- Optimized estimate of moveable volume fraction water (effective porosity in fully saturated conditions) from the ELAN analysis (dashed cyan curve and green area shading);
- Optimized estimate of total volume fraction of air-filled porosity from the ELAN analysis (solid red curve and dotted red area shading);
- Optimized estimate of water saturation (percentage of pore space filled with water) from the ELAN analysis (dashed-dotted purple curve);
- Water saturation as calculated directly from the bulk density and geochemical estimated porosity using a grain density of 3.05 g/cc (dotted light blue curve), 2.65 g/cc (long-dashed light blue curve), and 2.25 g/cc (dashed light blue curve)–with light blue shading between the 2.25 and 3.05 g/cc saturation curves to show the range;
- Integrated estimated relative water flow from the CMR log that mimics a flow meter (spinner) acquired under flowing conditions (solid green line coming from left-hand side at bottom of logged interval);

- Potential for water flow indicator from the CMR log (block cyan coming from the right-hand side of the track).

The porosity curves scale from 0 to 1 total volume fraction, left to right; the water saturation scales from 0 to 1 volume fraction of pore space, from left to right. The relative water flow is on a scale of 0 to 1 relative volumetric flow rate from left to right. The flow indicator is a binary-valued flag that rises to halfway through the first division from the right on the x-axis when the CMR measurement indicates a potential for flow.

Track 24–Depth

The final track on the right, same as the first track on the left, displays the depth below ground surface in units of feet, as measured by the geophysical logging system during the AIT-NGT logging run.

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Appendix C

Lithology Log

Appendix C
Lithologic Descriptions of Core and Drill Cuttings at Abandoned Borehole R-4

Geologic Unit	Lithologic Description	Sample Interval (ft)	Elevation Range (ft above msl)
Qal, alluvium	Unconsolidated sediments, sand (SW) with gravel and silt, brownish gray (5YR 4/1) grading to silt; sand composed of tuffaceous detrial materials likely derived from the Otowi Member of the Bandelier Tuff. Note: cored rock samples described in the interval 0 to 60.2 ft bgs.	0.0-1.4	6574.5-6573.1
	No core recovery.	1.4-3.0	6573.1-6571.5
	Unconsolidated sediments, silt (ML) with fine sand, light brownish gray (5YR 6/1), composed of loose ash plus quartz and sanidine crystals.	3.0-4.9	6571.5-6569.6
	No core recovery.	4.9-8.0	6569.6-6566.5
	Unconsolidated sediments, medium to coarse sand (SW) with silt and gravel, pale yellowish brown (10YR 6/2), pebble clasts (up to 3 mm); composed of volcanic ash, quartz and sanidine crystals, pumice, and dacite.	8.0-10.8	6566.5-6563.7
	No core recovery.	10.8-15.5	6563.7-6559.0
	Unconsolidated sediments, poorly graded fine to medium silty sand (SM), moderate brown (5YR 4/4); composed of tuffaceous sand and silt.	15.5-19.5	6559.0-6555.0
	No core recovery.	19.5-22.0	6555.0-6552.5
	Unconsolidated sediments, silt (ML) with fine sand, dark yellowish brown (10YR 4/2); composed of tuffaceous sand and silt.	22.0-23.2	6552.5-6551.3
	Unconsolidated sediments, well graded fine to coarse sand (SW), dark yellowish brown (10YR 4/2); tuffaceous composition indicated by the presence of grains of quartz and sanidine crystals, pumice, and volcanic lithics. Note: detritus likely derived from the Otowi Member of the Bandelier Tuff.	23.2-29.0	6551.3-6545.5
	No core recovery.	29.0-33.3	6545.5-6541.2
	Unconsolidated sediments, clayey sand (SC) with gravel, moderate brown (5YR 3/4); pebble clasts subangular (up to 2 cm), 20-25% clay matrix. Grains/clasts composed of pumice, abundant volcanic lithics, and quartz and sanidine crystals likely derived from the Otowi Member of the Bandelier Tuff.	33.3-35.8	6541.2-6538.7
	No core recovery.	35.8-38.0	6538.7-6536.5
	Unconsolidated sediments, clayey sand (SC) with gravel, moderate brown (5YR 3/4); color, texture, and composition similar to interval 33.0-35.8 ft.	38.0-38.4	6536.5-6536.1
Qbog, Guaje Pumice Bed	No core recovery. **Note: contact between base of Qal and underlying Guaje Pumice Bed is estimated at approximately 40 ft bgs.**	38.4-43.0	6536.1-6531.5
	Air-fall tuff, mottled coloration of white, moderate yellowish brown (10YR 5/4) dark yellowish brown (10YR 4/2), pumiceous. Strongly altered or weathered unit consists mainly of clay-altered, porphyritic pumice and white to dark brown, distinctively waxy clay. Altered pumices display phenocrysts of quartz, feldspar, and black pyroxene(?); relic fibrous structure.	43.0-48.0	6531.5-6526.5
	No core recovery.	48.0-49.0	6526.5-6525.5

Appendix C
Lithologic Descriptions of Core and Drill Cuttings at Abandoned Borehole R-4

Geologic Unit	Lithologic Description	Sample Interval (ft)	Elevation Range (ft above msl)
	Air-fall tuff/tuffaceous sediments, mottled coloration of white, moderate yellowish brown (10YR 5/4) and dark yellowish brown (10YR 4/2), pumiceous. Clay-altered porphyritic pumice and white to dark brown, waxy clay. Altered pumices contain phenocrysts of quartz, feldspar, and black pyroxene(?); relic fibrous structure. **Note: contact between basal Qbog and underlying Tpf is estimated at approximately 50 ft bgs.**	49.0-50.0	6525.5-6524.5
Tpf, Puye Formation	Tuffaceous sediments, clayey gravel (GC) with sand, mottled white and moderate brown (5YR 4/4), pumiceous. Composed of 35-45% subangular to subrounded white vitric pumice clasts (up to 1.0 cm), 2-3% quartz crystals, 1-2% volcanic lithic fragments (up to 0. 5 cm) in a matrix (40-50% volume) of clay and fine sand. Grades to fine sand with minor pumice fragments in the interval 57-58 ft.	50.0-58.0	6524.5-6516.5
	Tuffaceous sediments, silty fine sand (SM), grayish orange pink to light brown (5YR 5/6), pumice-bearing. Contains 1-3% clay-altered pumice fragments (up to 0.5 cm).	58.0-60.2	6516.5-6514.3
	Volcaniclastic sediments, gravel (GW) with sand, brown (10YR 5/4), subrounded pebbles up to 0.5 cm. +10F: dominantly porphyritic dacite clasts. Note: samples of drill cuttings are described from 60 to 843 ft bgs.	60.2-70	6514.3-6504.5
	Volcaniclastic sediments, gravel (GW) with sand, brown (10YR 5/4), subrounded to subangular clasts up to 3.0 cm. +10F: 85% porphyritic dacite clasts.	70-80	6504.5-6494.5
	Volcaniclastic sediments, gravel (GW) with sand, light brown gray (5YR 6/1). +10F: 20% subrounded dacite clasts.	80-85	6494.5-6489.5
	Volcaniclastic sediments, sand (SW) with gravel, light brown (10YR 5/4), fine to medium sand (up to 1 mm), subangular to angular grains. +10F: 85% dacite lithic grains/clasts.	85-105	6489.5-6469.5
	Volcaniclastic sediments, gravel (GW) with sand, moderate yellow brown (10YR 5/4). +10F: 20% subrounded dacite clasts.	105-120	6469.5-6454.5
	No cuttings returned; no sample available for examination.	120-140	6454.5-6434.5
	Volcaniclastic sediments, gravel (GW) with sand, moderate yellow brown (10YR 5/4). +10F: 20% subrounded dacite clasts.	140-150	6434.5-6424.5
	Volcaniclastic sediments, sandy silt (ML), moderate yellow brown (10YR 5/4), sand grains (up to 1 mm) dominantly composed of dacite, minor sanidine.	150-160	6424.5-6414.5
	Volcaniclastic sediments, sandy silt (ML), moderate yellow brown (10YR 5/4), sand grains (up to 1 mm) dominantly composed of dacite, minor sanidine.	160-170	6414.5-6404.5
	Volcaniclastic sediments, sandy silt (ML), moderate yellow brown (10YR 5/4), sand grains (up to 1.5 mm) dominantly composed of dacite, minor sanidine.	170-195	6404.5-6379.5
	Volcaniclastic sediments, sandy silt (ML), moderate yellow brown (10YR 5/4), fine to coarse sand (up to 2 mm), subrounded. WR/+10F: grains composed dominantly of dacite.	195-200	6379.5-6374.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish orange (10YR 6/6), pebble gravel (up to 2.0 cm), subangular to subrounded. +10F: gravel clasts composed of dacite and andesite.	200-210	6374.5-6364.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish orange (10YR 6/6), medium to coarse sand grains, pebble gravel (up to 2.0 cm), subangular to subrounded. +10F: gravel clasts composed of dacite and andesite.	210-240	6364.5-6334.5
	Volcaniclastic sediments, gravel (GW) with sand, dusky yellowish brown (10YR 2/2), pebble gravel (up to 1.5 cm), subangular. +10F: gravel clasts composed of dacite and andesite.	240-255	6334.5-6319.5

Appendix C
Lithologic Descriptions of Core and Drill Cuttings at Abandoned Borehole R-4

Geologic Unit	Lithologic Description	Sample Interval (ft)	Elevation Range (ft above msl)
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand with pebble gravel (up to 2.0 cm). +10F: gravel clasts composed of dacite and andesite.	255-275	6319.5-6299.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand with pebble gravel (up to 0.5 cm). +10F: gravel clasts composed of dacite and andesite.	275-280	6299.5-6294.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), coarse sand and pebble gravel (up to 1.5 cm). +10F: gravel clasts composed of dacite and andesite.	280-285	6294.5-6289.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), coarse sand and pebble gravel (up to 2 cm).	285-295	6289.5-6279.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), coarse sand and pebble gravel (up to 2.5 cm), subrounded.	295-315	6279.5-6259.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), coarse sand and pebble gravel (up to 2.5 cm), subrounded. +10F: volcanic clasts composed dominantly of andesite and dacite.	315-330	6259.5-6244.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand and pebble gravel (up to 1.0 cm), subrounded. +10F: volcanic clasts composed dominantly of andesite and dacite.	330-350	6244.5-6224.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand and pebble gravel (up to 1.5 cm), subrounded. +10F: volcanic clasts composed dominantly of andesite and dacite.	350-360	6224.5-6214.5
	Volcaniclastic sediments, gravel (GW) with sand, moderate reddish brown (10R 4/6), pebble gravel (up to 0.8 cm), subangular to subrounded. +10F: gravel clasts composed of dacite and andesite 1-3% friable weathered pumice fragments.	360-380	6214.5-6194.5
Tpp, pumiceous deposits (unassigned)	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand and pebble gravel (up to 1.5 cm), subrounded. +10F: volcanic clasts composed dominantly of andesite and dacite; up to 1% friable clay-altered pumice fragments (up to 2 mm).	380-390	6194.5-6184.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand and pebble gravel (up to 1.5 cm), subrounded. +10F: volcanic clasts composed dominantly of andesite and dacite; 3% white to very light gray, vitric pumice, pumices appear fresh and fibrous (i.e., exhibit elongate vesicular structure), up to 2 mm.	390-400	6184.5-6174.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), medium sand and pebble gravel (up to 1.0 cm); pumiceous. +10F: 80% volcanic clasts composed of andesite and dacite; 20% white, vitric pumice, up to 1 mm. +35F: 85% volcanic lithics, 15% pumice.	400-405	6174.5-6169.5
	Volcaniclastic sediments, gravel (GW) with sand, grayish orange (10YR 7/4), medium sand and pebble gravel (up to 1.5 cm), subrounded; pumiceous. +10F: 80% volcanic clasts composed of andesite and dacite; 20% white, vitric pumice, up to 1 mm.	405-415	6169.5-6159.5
	Volcaniclastic sediments, poorly graded sand (SP), grayish orange (10YR 7/4), medium sand, subrounded; pumiceous. +10F: mostly volcanic clasts composed of andesite and dacite; some orange clay-altered pumice fragments.	415-430	6159.5-6144.5
	Volcaniclastic sediments, sand (SW) with gravel, grayish orange (10YR 7/4), fine sand, gravel up to 0.5 cm, pumiceous. +10F: 50% volcanic clasts; 50% white and brown, clay-altered pumice fragments. Note: Base of Tpp based on lithodensity and CMR logs.	430-440	6144.5-6134.5

Appendix C
Lithologic Descriptions of Core and Drill Cuttings at Abandoned Borehole R-4

Geologic Unit	Lithologic Description	Sample Interval (ft)	Elevation Range (ft above msl)
Tf, Tertiary fanglomerate (unassigned)	Volcaniclastic sediments, poorly graded sand (SP), grayish orange (10YR 7/4), coarse sand (grains up to 3 mm); pumiceous. +35F: 10% volcanic grains composed of andesite and dacite; 90% pumice fragments, mostly clay altered, locally fresh. Note: High pumice content may be due to sloughing in the borehole or delayed circulation of cuttings from higher in the hole.	440-450	6134.5-6124.5
	Clastic sediments, sand (SW) with gravel, yellowish brown (10YR 2/2), subrounded gravel up to 0.75 mm, pumiceous. +10F: 75-80% volcanic clasts composed of andesite and dacite; 10-20% pumice fragments, mostly clay altered, locally fresh; 3-5% pink quartzite. Note: first appearance of Precambrian quartzite at 450 ft bgs.	450-475	6124.5-6099.5
	Clastic sediments, sand (SW) with gravel, yellowish brown (10YR 2/2), subrounded gravel up to 0.75 mm. +10F: 85-95% volcanic clasts composed of andesite and dacite; 3-5% pumice fragments, mostly clay altered; 3-5% pink and white quartzite.	475-480	6099.5-6094.5
	Clastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), medium sand (up to 2 mm), subrounded gravel (up to 1.0 cm). +10F: 95-98% volcanic clasts composed of andesite and dacite; 3-5% pinkish quartzite.	480-500	6094.5-6074.5
	Clastic sediments, sand (SW) with gravel to gravel (GW) with sand, dark yellowish brown (10YR 4/2), subrounded gravel (up to 2.0 cm). +10F: 95-98% volcanic clasts composed of andesite and dacite; 3-5% pinkish quartzite.	500-510	6074.5-6064.5
	Clastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), subrounded and broken gravel clasts (up to 2.0 cm). +10F: 97% volcanic clasts composed of andesite and dacite; 3% quartzite.	510-520	6064.5-6054.5
	Clastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), subrounded clasts (up to 0.5 cm). +10F: 95-97% volcanic clasts composed of andesite and dacite; 3-5% quartzite.	520-530	6054.5-6044.5
	Clastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 2.3 cm). +10F: 95% dacite clasts; 5% quartzite.	530-540	6044.5-6034.5
	Clastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 0.5 cm). +10F: 95-97% dacite clasts; 3-5% quartzite.	540-545	6034.5-6029.5
	Clastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 1.0 cm). +10F: 97-99% dacite clasts; trace quartzite.	545-565	6029.5-6009.5
	Clastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 2.0 cm). +10F: mostly dacitic volcanic clasts; trace quartzite.	565-580	6009.5-5994.5
	Clastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 1.0 cm). +10F: mostly dacitic volcanic clasts; minor quartzite clasts. Note: last appearance of Precambrian quartzite in sample at 590 ft bgs.	580-590	5994.5-5984.5
	Volcaniclastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 0.75 cm). +10F: mostly dacitic volcanic clasts; minor clay-altered pumice fragments.	590-600	5984.5-5974.5
	Volcaniclastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), gravel clasts (up to 0.25 cm), pumiceous. +10F: 75% dacitic volcanic clasts; 25% pumice fragments. **Note: pumice diminishes below ~ 610 ft.**	600-610	5974.5-5964.5
	Volcaniclastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 1.5 cm), pumiceous. +10F: 80% dacitic volcanic clasts; 20% pumice fragments.	610-620	5964.5-5954.5

Appendix C
Lithologic Descriptions of Core and Drill Cuttings at Abandoned Borehole R-4

Geologic Unit	Lithologic Description	Sample Interval (ft)	Elevation Range (ft above msl)
	Volcaniclastic sediments, sand (SW) with gravel, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 2.0 cm). +10F: 99% dacitic volcanic clasts. Note: sample contains no pumice.	620-630	5954.5-5944.5
	Volcaniclastic sediments, gravel (GW) with sand, dark yellowish brown (10YR 4/2), subrounded gravel clasts (up to 2.0 cm). +10F: 99% dacitic volcanic clasts. Note: sample contains no pumice.	630-640	5944.5-5934.5
	Volcaniclastic sediments, gravel (GW) with sand, yellowish brown (10YR 2/2), subrounded to broken gravel clasts (up to 3.0 cm), probable cobble gravel interval. +10F: mostly volcanic clasts composed of dacite and basalt; quartzite and granite clasts common.	640-650	5934.5-5924.5
	Volcaniclastic sediments, gravel (GW) with sand, yellowish brown (10YR 2/2), well rounded to broken gravel clasts (up to 3.0 cm), abundant broken chips suggest coarse gravel interval with abundant cobble-size clasts. +10F: 50% andesite clasts; 50% basalt clasts.	650-660	5924.5-5914.5
	Volcaniclastic sediments, sand (SW) with gravel, yellowish brown (10YR 2/2), subrounded gravel clasts (up to 2.0 cm). +10F: clasts composed mostly of volcanic rocks.	660-665	5914.5-5909.5
	Volcaniclastic sediments, gravel (GW) with sand, yellowish brown (10YR 2/2), subrounded gravel clasts (up to 2.0 cm). +10F: clasts composed of dacite and andesite.	665-675	5909.5-5899.5
	Volcaniclastic sediments, gravel (GW) with sand, yellowish brown (10YR 2/2), subrounded gravel clasts (up to 2.0 cm). +10F: clasts composed mostly of volcanic rocks including dacite and basalt; trace quartzite.	675-680	5899.5-5894.5
	Volcaniclastic sediments, sand (SW) with gravel, yellowish brown (10YR 2/2), subrounded gravel clasts (up to 2.0 cm). +10F: clasts composed mostly of dacite and basalt.	680-690	5894.5-5884.5
	Volcaniclastic sediments, gravel (GW) with sand, yellowish brown (10YR 2/2), subrounded and broken gravel clasts (up to 3.5 cm). +10F: clasts composed mostly of dacite and basalt.	690-705	5884.5-5869.5
	Volcaniclastic sediments, sand (SW) with gravel, pale yellowish brown (10YR 6/2), clasts up to 1.0 cm. +10F: clasts composed mostly of dacite and basalt(?); up to 10-20% white altered pumice.	705-720	5869.5-5854.5
	Volcaniclastic sediments, sand (SW) with gravel, pale yellowish brown (10YR 6/2), clasts up to 1.0 cm. +10F: clasts composed mostly of dacite and basalt(?); minor altered pumice; trace quartzite.	720-730	5854.5-5844.5
	Volcaniclastic sediments, sand (SW) with gravel, pale yellowish brown (10YR 6/2), clasts up to 2.0 cm. +10F: volcanic clasts composed mostly of dacite; less than 10% pumice.	730-745	5844.5-5829.5
	Volcaniclastic sediments, sand (SW) with gravel, pale yellowish brown (10YR 6/2), subrounded clasts up to 2.0 cm. +10F: volcanic clasts dominantly dacite; less than 1% pumice; trace quartzite.	745-755	5829.5-5819.5
	Volcaniclastic sediments, sand (SW) with gravel, pale yellowish brown (10YR 6/2), subrounded clasts up to 2.5 cm. +10F: volcanic clasts dominantly andesite.	755-765	5819.5-5809.5
	Volcaniclastic sediments, sand (SW) with gravel to gravel (GW) with sand, pale yellowish brown (10YR 6/2), subrounded clasts up to 2.75 cm. +10F: volcanic clasts dominantly dacite; trace pumice.	765-780	5809.5-5794.5
	Volcaniclastic sediments, sand (SW) with gravel, pale yellowish brown (10YR 6/2), fine to medium sand, subrounded gravel clasts up to 1.0 cm. +10F: volcanic clasts dominantly dacite.	780-790	5794.5-5784.5
	Volcaniclastic sediments, gravel (GW) with sand, pale yellowish brown (10YR 6/2), fine to medium sand, subrounded gravel clasts up to 1.0 cm. +10F: volcanic clasts dominantly dacite; trace quartzite.	790-800	5784.5-5774.5

Appendix C
Lithologic Descriptions of Core and Drill Cuttings at Abandoned Borehole R-4

Geologic Unit	Lithologic Description	Sample Interval (ft)	Elevation Range (ft above msl)
	Volcaniclastic sediments, gravel (GW) with sand, pale yellowish brown (10YR 6/2), subrounded gravel clasts up to 2.5 cm. +10F: volcanic clasts dominantly dacite; minor quartzite and quartz-mica schist; trace crystal-rich tuff.	800-815	5774.5-5759.5
	Volcaniclastic sediments, gravel (GW) with sand, pale yellowish brown (10YR 6/2), subrounded gravel clasts up to 2.5 cm. +10F: volcanic clasts dominantly dacite; trace quartzite.	815-835	5759.5-5739.5
	No sample collected.	835-843	5739.5-5731.5
	TOTAL BOREHOLE DEPTH (TD) IS AT 843 FT BGS.		

Note: American Society for Testing Materials (ASTM) standards were used in describing the texture of drill chip samples for sedimentary rocks such as alluvium and the Puye Fanglomerate. ASTM method D 2488-90 incorporates the Unified Soil Classification System (USCS) as a standard for field examination and description of soils. The following is a glossary of standard USCS symbols used in the Well R-4 lithlog.

GW – Well graded gravel
GP – Poorly graded gravel
ML – Silt
SW – Well-graded sand
SP – Poorly graded sand
SM – Silty sand
SC – Clayey sand
GC – Clayey gravel

REFERENCE

ASTM D 2488-90. Standard Practice and Identification of Soils (Visual-Manual Procedure)

*Colors were determined from comparison with Munsell® color chips as found in the Geological Society of America Rock-Color Chart.

Note: Cuttings were collected at nominal 5-ft intervals and divided into three sample splits: (1) unsieved, or whole rock (WR), sample; (2) +10F sieved fraction (No. 10 sieve equivalent to 2.0 mm); and (3) +35F sieved fraction (No. 35 sieve equivalent to 0.50 mm).

Note: The term "per cent", as used in the above descriptions, refers to per cent by volume for a given sample component.

Appendix D

Hydrologic Test Report and Hydrologic Test Data
(CD on inside back sleeve)

R-4 PUMPING TEST ANALYSIS

INTRODUCTION

This section describes the analysis of the constant-rate pumping test data obtained from three pumping tests conducted on R-4. The primary objective of the analysis was to determine the hydraulic properties of the sediments screened in R-4. A secondary objective was to compare the performance of newly-acquired barometric pressure monitoring equipment procured for the project to the barometric pressure readings obtained locally from LANL's RRES – Meteorology and Air Quality group.

Data are presented here from three separate pumping tests. In both Tests 1 and 2, improperly manufactured drop pipe permitted water to leak back into the well during recovery, affecting the data set. The problem was diagnosed, the pipe replaced, and Test 3 was conducted.

For each test, data were collected during background monitoring, pumping and recovery. The Christmas holiday shutdown fell between Tests 2 and 3 and provided an opportunity to obtain an extensive set of useful background data.

Test 1 was started at 3:17 pm on December 16, 2003, and continued until 3:17 pm on December 17. The pumping rate was initially 13.7 gpm, but declined to 13.1 gpm later in the test. It is possible that the leakage rate through the defective drop pipe changed during the test, affecting the discharge rate from the well.

Test 2 was started at 1:45 PM on December 19 and continued until 1:41 pm on December 20. The initial pumping rate was 13.4 gpm, declining to 13.27 gpm later in the test.

Test 3 was started at 9:10 am on January 6, 2004, and was stopped at 3:10 pm that same day. The discharge rate was maintained at a constant rate of 13.9 gpm for the duration of the test.

BACKGROUND DATA

Background water level data were collected in conjunction with running the pumping tests. Collecting background data allows the analyst to see what water level fluctuations occur naturally in the aquifer and helps distinguish between water level changes caused by conducting the pumping test and changes associated with other causes.

Background water level fluctuations have several causes, among them barometric pressure changes, operation of other wells in the aquifer, earth tides and long-term trends related to weather patterns. The background data hydrographs from the R-4 tests were compared to barometric pressure data from the area to determine if a correlation existed.

Barometric pressure data were obtained from the Los Alamos National Laboratory TA-54 tower site from RRES-Meteorology and Air Quality. The TA-54 measurement location is at an elevation of 6,548 feet (ft) above mean sea level (amsl), whereas the wellhead elevation is 6,577 ft amsl. Furthermore, the static water level in R-4 is about 736 ft below land surface, making the water table elevation 5,841 ft amsl. Therefore, the measured barometric pressure data from TA-54 had to be adjusted to reflect the pressure at the elevation of the water table within R-4.

The following formula was used to adjust the measured barometric pressure data:

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R4} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R4}}{T_{WELL}}\right)\right]$$

where,

P_{WT}	=	barometric pressure at the water table inside R-4
P_{TA54}	=	barometric pressure measured at TA-54
g	=	acceleration of gravity, in m/sec^2 (9.80665 m/sec2)
R	=	gas constant, in J/Kg/degree Kelvin (287.04 J/Kg/degree Kelvin)
E_{R4}	=	land surface elevation at R-4, in feet (6,577 ft)
E_{TA54}	=	elevation of barometric pressure measuring point at TA-54, in feet (6,548 ft)
E_{WT}	=	elevation of the water level in R4, in feet (5,841 ft)
T_{TA54}	=	air temperature near TA-54, in degrees Kelvin (assigned a value of 27 degrees Fahrenheit, or 270.4 degrees Kelvin)
T_{WELL}	=	air temperature inside R-4, in degrees Kelvin (assigned a value of 70 degrees Fahrenheit, or 294.3 degrees Kelvin)

This formula is an adaptation of an equation provided by RRES-Meteorology and Air Quality. It can be derived from the ideal gas law and standard physics principles. An inherent assumption in the derivation of the equation is that the air temperature between TA-54 and the well is temporally and spatially constant, and that the temperature of the air column in the well is similarly constant.

The corrected barometric pressure data reflecting pressure conditions at the water table were compared to water level hydrographs to discern the correlation between the two.

In addition to the TA-54 barometric pressure data, an Insitu recording barometer (BaroTROLL) was procured for the project to enhance barometric data collection. The TA-54 site reports pressure data in 15-minute intervals. However, in some instances it is advantageous to have barometric pressure data recorded at the same frequency as water level data so that barometric corrections to the water levels can be computed easily. Therefore, the BaroTROLL was obtained because it can be programmed to mimic the data collection pattern produced by the down-hole transducer. In the R-4 testing, the BaroTROLL output was compared to the TA-54 data to verify the accuracy of the new equipment.

TIME-DRAWDOWN ANALYSIS

The drawdown data were analyzed using the Cooper-Jacob method (1946), a simplification of the Theis equation (1935) that is mathematically equivalent to the Theis equation for pumped well data. The Cooper-Jacob equation describes drawdown around a pumping well as follows:

$$s = \frac{264Q}{T} \log \frac{0.3Tt}{r^2 S}$$

where,

s	=	drawdown, in feet
Q	=	discharge rate, in gpm
T	=	transmissivity, in gpd/ft
t	=	pumping time, in days
r	=	distance from center of pumpage, in feet
S	=	storage coefficient (dimensionless)

The Cooper-Jacob equation is a simplified approximation of the Theis equation and is valid whenever the u value is less than about 0.05, where u is defined as follows:

$$u = \frac{1.87r^2S}{Tt}$$

For small radius values (e.g., corresponding to borehole radii), u is less than 0.05 at very early pumping times and, therefore, is less than 0.05 for all measured drawdown values. Thus, for the pumped well, the Cooper-Jacob equation can be considered a valid approximation of the Theis equation.

According to the Cooper-Jacob method, the time-drawdown data are plotted on a semilog graph, with time plotted on the logarithmic scale. Then a straight line of best fit is constructed through the data points and transmissivity is calculated using:

$$T = \frac{264Q}{\Delta s}$$

where,

T	=	transmissivity, in gpd/ft
Q	=	discharge rate, in gpm
Δs	=	change in head over one log cycle of the graph, in feet

Storage coefficient calculation can only be performed using observation well data. Therefore, only transmissivity was computed from the R-4 pumping tests.

In applying the time-drawdown (and recovery) analysis methods, it is necessary to screen out early data that have been affected by casing storage. These are data points that fall off the theoretical response curve because of the time it takes for the pump to evacuate the volume of water stored in the well casing. Screening these data points is essential, because it is not possible to determine aquifer parameters from the casing storage affected data. Application of standard analytical protocols to the casing storage affected data will produce erroneous aquifer parameter values.

The duration of casing storage effects can be estimated using the following equation (Schafer, 1978).

$$t_c = \frac{0.6\left(D^2 - d^2\right)}{\frac{Q}{s}}$$

where,

t_c = duration of casing storage effect, in minutes
D = inside diameter of well casing, in inches (4.5 inches)
d = outside diameter of column pipe, in inches (1.315 inches)
Q = discharge rate, in gpm
s = drawdown observed in pumped well at time t_c, in feet

In some wells, a secondary casing storage effect can be caused by drainage of the filter packed annulus outside the well casing. When this occurs, the duration of casing storage is even greater and can be approximated as follows:

$$t_c = \frac{0.6\left[\left(D^2 - d^2\right) + S_y\left(4r_w^2 - D_O^2\right)\right]}{\frac{Q}{s}}$$

In this equation, r_w is the borehole radius, in inches; D_O is the outside diameter of the well casing, in inches; and S_y is the short-term drainable porosity of the filter pack (analogous to short-term specific yield). The value of S_y can be expected to range between about 10 and 20 percent in most cases.

This equation is used in conjunction with the data plot to solve for t_c using an iterative procedure. The calculation generally produces a conservative value of t_c, that is, t_c generally equals or exceeds the effective casing storage duration. The pumping test data approach the theoretical Theis or Cooper-Jacob trend asymptotically and, often times, the casing storage response is effectively completed in about half the time suggested by the theoretical t_c value. Therefore, once t_c has been calculated, the casing storage duration is usually assumed to fall between 50 and 100 percent of the computed t_c value.

RECOVERY ANALYSIS

Recovery data were analyzed by the Theis Recovery Method. This is a semi-log analysis method similar to the Cooper-Jacob procedure.

In this method, residual drawdown is plotted on a semi-log graph versus the ratio t/t', where t is the time since pumping began and t' is the time since pumping stopped. A straight line of best fit is constructed through the data points and T is calculated from the slope of the line as follows:

$$T = \frac{264Q}{\Delta s}$$

The recovery data are particularly useful compared to time-drawdown data. Because the pump is not running, spurious data response associated with dynamic discharge rate fluctuations are eliminated. The result is that the data set is generally "smoother" and easier to analyze.

THICK AQUIFER RESPONSE

A complicating aspect of the R-well pumping tests is that the wells are severely partially penetrating. The typical well design incorporates a relatively short well screen (a few feet to tens of feet in length) installed within a massively thick aquifer (many hundreds of feet or more). As a result, during pumping, the cone of depression expands not only horizontally, but also vertically, throughout the test. As the cone intercepts a greater and greater aquifer thickness, the data plot reflects a steadily flattening slope, corresponding to the continuously increasing vertical height of the zone of investigation. As a result, later data tend to produce a greater calculated transmissivity than do early data. This complicates the analysis because, for any given slope (or transmissivity value), it is not possible to know what the corresponding aquifer thickness is (vertical extent of the cone of depression).

If an aquitard is encountered at depth, limiting the vertical growth of the cone of depression, the data curve may reach a steady slope, reflecting the transmissivity of the sediments above the aquitard. In that case, a definitive transmissivity can be determined and the hydraulic conductivity can be calculated by dividing the transmissivity by the saturated thickness above the aquitard (if that dimension is known). If no aquitard is encountered, the drawdown curve gets steadily flatter, reflecting a continuum of transmissivities corresponding to the effective depth of the cone of depression at any given time.

Importance of Early Data

When pumping or recovery first begins, the vertical extent of the cone of depression is limited to approximately the well screen length. For most R-well pumping tests, these first few moments of pumping are the only time that the effective height of the cone of depression is known with certainty. Thus, the early data potentially offer the best opportunity to obtain hydraulic conductivity information, because conductivity would equal the earliest-time transmissivity divided by the well screen length.

Unfortunately, in the R-wells, casing storage effects dominate the early-time data, making it impossible to determine the transmissivity of just the screened interval. In some instances, it may be possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval prior to conducting the test. Therefore, this option will be investigated and pursued for the R-well testing program.

Note that, because the R-wells are partially penetrating, an alternate model available for analyzing the data is the Hantush equation for partially penetrating wells. However, this method introduces four additional unknown parameters not included in the Cooper-Jacob analysis presented above – vertical hydraulic conductivity, storage coefficient, location of top of aquifer, and location of bottom of aquifer. Unless very early data are obtained, there is no advantage in applying the Hantush equation because the multiple unknown parameters cannot be sufficiently constrained to support a definitive solution. To constrain the solution, it is necessary to have very early data and, in the R-4 tests, casing storage effects masked the early data. Therefore, the Hantush approach is not included in this report. However, plans are underway to conduct future R-well tests using an inflatable packer above the pump to eliminate casing storage effects, so that early valid data can be obtained. For such tests, the Hantush method will be investigated to see whether it offers any advantage over other methods for data analysis.

It is important to note that employing a packer will eliminate only the casing storage effects caused by drainage of the water volume stored within the well casing itself. The secondary casing storage effect of filter pack drainage could still occur in some situations. Nevertheless, the implementation of a down-hole packer should be pursued for those settings where its use is appropriate.

SPECIFIC CAPACITY ANALYSIS

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas that are based on the assumption that the pumped well is 100 percent efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100 percent efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is unknown, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

For fully penetrating wells, the Cooper-Jacob equation can be iterated to solve for the lower-bound hydraulic conductivity. However, the Cooper-Jacob equation (assuming full penetration) ignores the contribution to well yield from permeable sediments above and below the screened interval. To account for this contribution, it is necessary to use a computation algorithm that includes the effects of partial penetration. One such approach was introduced by Brons & Marting (1961) and augmented by Bradbury & Rothchild (1985).

Brons and Marting introduced a dimensionless drawdown correction factor, s_P, approximated by Bradbury and Rothschild as follows:

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right]$$

In this equation, L is the well screen length, in feet. Incorporating the dimensionless drawdown parameter, the conductivity is obtained by iterating the following formula:

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right)$$

To apply this formula, a storage coefficient value must be assigned. Storage coefficient values for unconfined sand and gravel aquifers, such as the Puye Formation in which many of the R-wells are completed, typically range from a few percent to 20 percent or more, with the majority of the values falling between approximately 5 and 15 percent. Thus, in the absence of site-specific storage coefficient data for the Puye, a value of 0.1 is deemed to be a reasonable choice for performing the calculations for unconfined conditions. When confined conditions are encountered, the storage coefficient can be expected to range from about 10^{-5} to 10^{-3}, depending on aquifer thickness (the thicker the aquifer, the greater the storage coefficient). Typically, a value of 5×10^{-4} may be assigned for calculation purposes. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate of the storage coefficient is adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b, which is generally not known. Fortunately, the calculated value of hydraulic conductivity is usually insensitive to the selected aquifer thickness value, as long as the aquifer thickness is significantly greater than the screen length. This is because saturated aquifer materials far above or below the screened interval contribute little to the yield of the well. Thus, it was expected that an approximate aquifer thickness estimate would suffice for the calculations.

Computing the lower-bound estimate of hydraulic conductivity can provide a useful frame of reference for evaluating the other pumping test calculations.

TESTS 1 AND 2

Tests 1 and 2 were run before the Christmas break, beginning on December 16 and December 19, respectively. Water levels were recorded before and after each test.

Figure 1 shows a comparison of the barometric pressure and the water level hydrograph obtained from R-4 from December 15 to December 24. All figures are presented at the end of this report, Appendix D. Background water levels fluctuated about half a foot during this period, primarily in response to barometric pressure changes. It can be seen that the magnitude of the water level changes is similar to that of the barometric pressure changes, indicating that R-4 is nearly 100 percent barometrically efficient. Barometric efficiency is defined as the ratio of water level change to barometric pressure change, expressed as a percentage. (Note that this term has no relationship to well efficiency.)

Figure 1 shows a subtle but steady rise in the background water level in R-4, as evidenced by the relative positions of the hydrograph and barometric pressure curve on the left side of the graph compared to the right side, i.e., the water level is rising in relation to the barometric pressure.

It is evident from Figure 1 that most of the background water level changes in R-4 are a result of barometric pressure changes.

Test 1 Drawdown

During Test 1, R-4 was pumped from 3:17 pm on December 16 to 3:17 pm on December 17. Figure 2 shows the resulting time-drawdown plot. Because of the defects in the drop pipe, water standing in the drop pipe prior to the test had drained from the pipe into the well, emptying much of the drop pipe. As a result, the pump initially operated against low head and, therefore, produced a greater discharge rate than anticipated. This accounts for the rapid dewatering of the well casing and the "overshoot" in the magnitude of the drawdown during the first two minutes of pumping.

Once the pumping rate was stabilized to a little over 13 gpm, the water levels remarkably rose throughout the remainder of the test. The discharge rate declined steadily from 13.7 gpm to 13.1 gpm during the test. However, the magnitude of water level rise exceeded what would be predicted based on the discharge rate reduction alone. Therefore, the conclusion was that the well efficiency had increased during the test, i.e., the well continued to develop, simply by pumping.

The "ripple" in the data trace late in the test was a result of changes in barometric pressure.

The chaotic and unusual response shown on Figure 2 precluded calculation of aquifer coefficients from the Test 1 drawdown data.

Test 1 Recovery

Figure 3 shows the recovery data from Test 1. The casing storage calculation revealed a tc a little more than 7 minutes. Thus, it was expected that the effects of casing storage would persist for roughly 4 to 7 minutes, i.e., between about 50 and 100 percent of the calculated value. This corresponded to a t/t' ratio between about 360 and 200.

Before the casing storage period had elapsed, a water level rise above static occurred, starting at a t/t' value of about 500, as shown on Figure 3. It was theorized that a leak in the drop pipe within a couple hundred feet of land surface had allowed water to backflow and run down the outside of the drop pipe to the water table. The influx of water caused the "mound" evidenced on the recovery graph, starting at a t/t' value of 500, about 3 minutes after pumping stopped. The 3-minute delay is probably the travel time of the backflow pulse down the outside of the drop pipe.

The combination of casing storage and the backflow event precluded analyzing the data.

Test 2 Drawdown

Figure 4 shows the time-drawdown graph for Test 2. Unlike Test 1, Test 2 was begun with the drop pipe full of water. Thus, the pumping rate was maintained at nearly a constant rate. The early, steep portion of the data curve shows casing storage effects. The calculated tc value was about 6 minutes, suggesting an effective casing storage duration of approximately 3 to 6 minutes. A little over a half hour into the test, the discharge rate was adjusted resulting in the data offset observed at that location on the graph. Overall, Figure 4 illustrates that the Test 2 drawdown data show the typical R-well response of steady flattening of the data trace over time, as the cone of depression grows vertically through greater and greater sediment thickness.

Figure 5 shows the same data on an expanded vertical scale. Between the casing storage portion of the curve and the discharge rate adjustment, the data were orderly in appearance. Later in the test, the data showed chaotic water level movement. It was hypothesized that these cyclic water level fluctuations were barometrically induced. Figure 6 shows a comparison of the barometric pressure and the irregular pumping water levels, confirming that the fluctuations were, indeed, caused by barometric pressure changes.

Figure 7 shows the drawdown data plotted on a scale that has been expanded both vertically and horizontally for clarity. The window of data, between casing storage and the discharge rate adjustment, showed progressive flattening. The earliest data following casing storage revealed a transmissivity of 30,000 gallons per day per foot (gpd/ft). This transmissivity corresponded to a sediment thickness substantially greater than the well screen length of 23 ft, because the pumping time was sufficient for significant vertical growth of the cone of depression.

Dividing the transmissivity by the screen length of 23 ft yielded a hydraulic conductivity of 1,300 gallons per day per square foot (gpd/ft^2), or 174 ft per day. Therefore, dividing the transmissivity by a substantially greater sediment thickness would yield a hydraulic conductivity much less than 174 ft per day. In other words, it can be expected that the actual hydraulic conductivity would be just a fraction of 174 ft per day. Further refinement of the conductivity value was not possible, because it was not possible to know the vertical extent of the cone of depression corresponding to the pumping time for which the transmissivity calculation was made.

Between 10 minutes and 35 minutes of pumping, the slope of the data trace flattened, showing a transmissivity of 80,000 gpd/ft. After 35 minutes of pumping, the data were too erratic to determine whether additional flattening of the cone of depression had occurred. The observed, and possibly continuing, flattening suggests very high aquifer transmissivity.

An alternate explanation for the flattening of the drawdown curve is delayed yield. In unconfined aquifers, delayed yield (drainage of the upper portions of the aquifer above the cone of depression), rather than high transmissivity, can account for flattening of the drawdown curve. However, such flattening is only temporary and must inevitably be followed by a resumed steep slope, reflecting the actual transmissivty. No such resumption of a steep slope was detected in any of the pumping tests conducted in R-4. It appears that late time data show essentially no change, other than response to barometric pressure changes. This confirms that the high transmissivity calculation was not a false value caused by delayed yield. It confirms that the transmissivity of the sediments is very high at the R-4 location.

Test 2 Recovery

Figure 8 shows the recovery data set from Test 2. As was the case with Test 1, leakage from the drop pipe caused a "mounding" event after several minutes of recovery. The combination of casing storage and leakage from the drop pipe rendered the data set non-analyzable.

TEST 3

The Test 3 pumping period lasted for six hours, from 9:10 am until 3:10 pm on January 6, 2004. Prior to the test, background water levels were measured over the Christmas break so that the R-4 hydrograph could be compared to the barometric pressure record.

Figure 9 shows a comparison of barometric pressure and the water levels measured in R-4 from December 24, 2003 until January 5, 2004. The two curves appear similar, except there appears to be a steady rise in water levels in relation to barometric pressure. The average water level rise was approximately 0.0135 ft per day during the period of record.

Figure 10 shows comparative plots of the barometric pressure change at the water table, corrected for 95 percent barometric efficiency, and the hydrograph with the background trend of 0.0135 ft per day water level rise subtracted out. The two curves nearly coincide, within one or two hundredths of a foot, confirming that the background water levels were influenced almost exclusively by the steady background trend (0.0135-ft-per-day water level rise) and the barometric pressure changes.

As part of the barometric pressure evaluation, the BaroTROLL data were compared to the barometric pressure data reported from TA-54. Figure 11 illustrates a 24-hour record of the two sources of barometric pressure data, from noon January 6 until noon January 7, that show that they were similar, but not identical. It is possible that the BaroTROLL readings were affected by windy conditions that existed at the site.

For the next 24-hour monitoring period, from noon January 7 until noon January 8, the BaroTROLL was moved to a sheltered location (indoors) in Los Alamos. Figure 12 shows a comparison of the barometric pressure records for this period, corrected for the difference in elevation. According to Figure 12, the two barometric pressure data sets agreed fairly well, especially during the last half of the monitoring period depicted on the graph.

The barometric pressure data were compared to the R-4 hydrograph for the period just prior to the pumping test. Figure 13 shows that the two patterns were similar. On Figure 14, the barometric pressure data were adjusted for 95 percent barometric efficiency and show a good fit with the water level data. Both of these comparisons used barometric pressure data from TA-54.

Post-test water level data also were compared to barometric pressure data, this time using the BaroTROLL data. As shown on Figure 15, the results were similar, though not identical. This corresponded to the time period when the BaroTROLL was on site and possibly being affected by wind.

Test 3 Drawdown

Figure 16 shows the time-drawdown graph for Test 3, while Figure 17 shows the same data on an expanded scale. The early data were affected by casing storage. The calculated value of tc was about 6 minutes, suggesting an effective casing storage duration of between 3 and 6 minutes. During this time period, the data showed a distinct "step" a few minutes into the test. It is possible that ice in the discharge piping may have temporarily restricted the flow slightly, causing the observed response.

The earliest data after casing storage effects diminished showed a transmissivity of 19,700 gpd/ft, from about 6 minutes to 15 minutes. Using the screen length as the divisor to calculate hydraulic conductivity yielded a value of approximately 860 gpd/ft^2, or 115 ft per day. However, the appropriate divisor would have exceeded the screen length substantially because of vertical expansion of the cone of depression during the first 15 minutes of pumping. This means that the actual hydraulic conductivity can be expected to have a value just a fraction of the calculated value of 115 ft per day.

During the final hours of pumping, the water levels rose more than 0.2 ft in R-4. During this time, the barometric pressure dropped only 0.1 ft. Thus, half of the observed rise in water levels was not accounted for by the barometric pressure changes and might be related to subtle discharge rate variations and/or additional increases in well efficiency during pumping

Test 3 Recovery

The recovery data for Test 3 are shown on Figure 18. It is apparent that casing storage effects dominate the early data.

The recovery data were plotted on an expanded scale on Figure 19. Surprisingly, the water levels rose for only about half an hour and then declined nearly a tenth of a foot during the remainder of the monitoring period. The very late data show oscillations caused by barometric pressure changes.

The water levels on Figure 19 were adjusted mathematically to factor out the barometric effect and re-plotted on Figure 20. Even with the barometric pressure effect eliminated from the data set, the graph still showed water levels declining during most of the recovery period. This response was very different than the water level response observed during the two weeks prior to the test in which the water levels rose uniformly at 0.0135 ft per day. There was no apparent explanation for the unusual recovery response.

On Figure 20 the earliest data following the casing storage portion of the curve were analyzed to determine transmissivity. The resulting value, based on data after about 2.8 minutes of recovery, was 43,600 gpd/ft. It is expected that this value represents the transmissivity of a sediment thickness substantially greater than the 23-ft well screen length. Dividing this transmissivity by the screen length produced a hydraulic conductivity value of 1,900 gpd/ft^2, or about 250 ft per day. It follows that the actual hydraulic conductivity would be expected to be substantially less than this, probably just a fraction of 250 ft per day.

Had the pumping test been run using an inflatable packer above the pump and screen, it would have been possible to eliminate the casing storage effects. This would have made it possible to measure the very early aquifer response to pumping, when the height of the cone of depression corresponded roughly to the well screen length. The resulting aquifer transmissivity would have supported calculation of a more accurate hydraulic conductivity estimate than is possible with the current data set.

Test 3 Specific Capacity

Test 3 produced approximately 13.9 gpm with 7.15 ft of drawdown. This information was used to calculate a lower-bound estimate of hydraulic conductivity using the Brons and Marting method described earlier. Calculations were performed using an assumed aquifer thickness of 200 ft and an unconfined storage coefficient of 0.1. These values were as good as any, considering the insensitivity of the calculations to these parameters. The resulting lower-bound hydraulic conductivity value was 10.1 ft per day.

SUMMARY

The following information has been determined from the pumping and recovery tests on R-4:

1. Water levels in R-4 responded to barometric pressure changes with a barometric efficiency of approximately 95 percent.
2. Casing storage effects dominated the early drawdown and recovery response, making is impossible to accurately estimate the transmissivity and hydraulic conductivity of the screened interval.
3. Drawdown and recovery data obtained from R-4 showed the pattern of steady flattening, consistent with a severely partially penetrating well in a massively thick and highly transmissive aquifer.
4. The specific capacity of R-4 yielded a lower-bound hydraulic conductivity value of 10.1 ft per day.
5. The transmissivity of the sediments penetrated by the cone of depression is very high, likely in excess of 100,000 gpd/ft.
6. Exaggerated "upper bounds" for hydraulic conductivity included values of 174 ft per day, 115 ft per day, and 250 ft per day. That is, the hydraulic conductivity is expected to be just a fraction of these values.
7. In some instances, it may be possible to obtain better test data in the future by using an inflatable packer above the pump to eliminate casing storage effects that mask the early-time response.

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Figure 1. Comparison of R-4 Hydrograph and Barometric Pressure - Tests 1 and 2

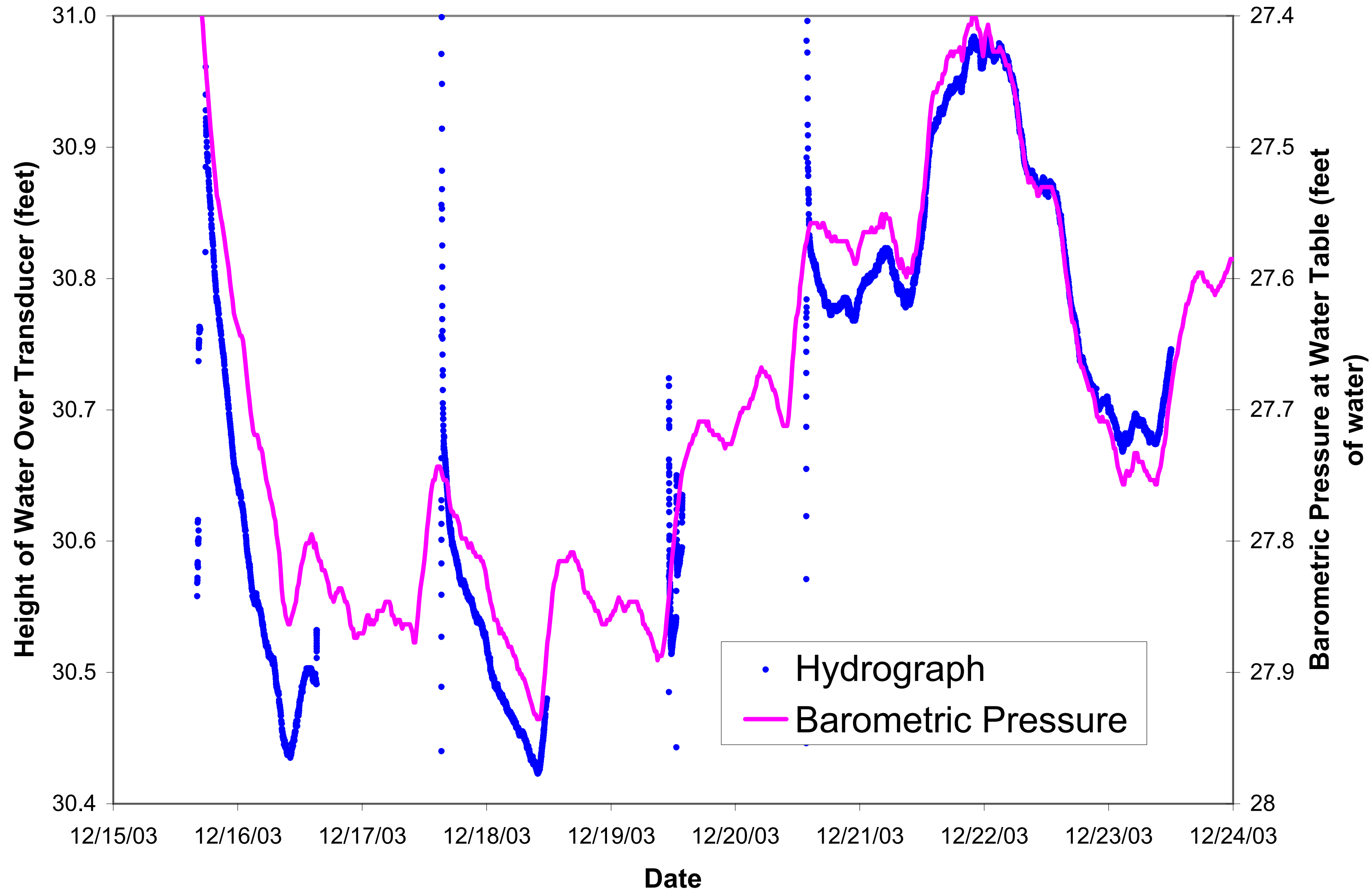


Figure 2. Well R-4 Drawdown - Test 1

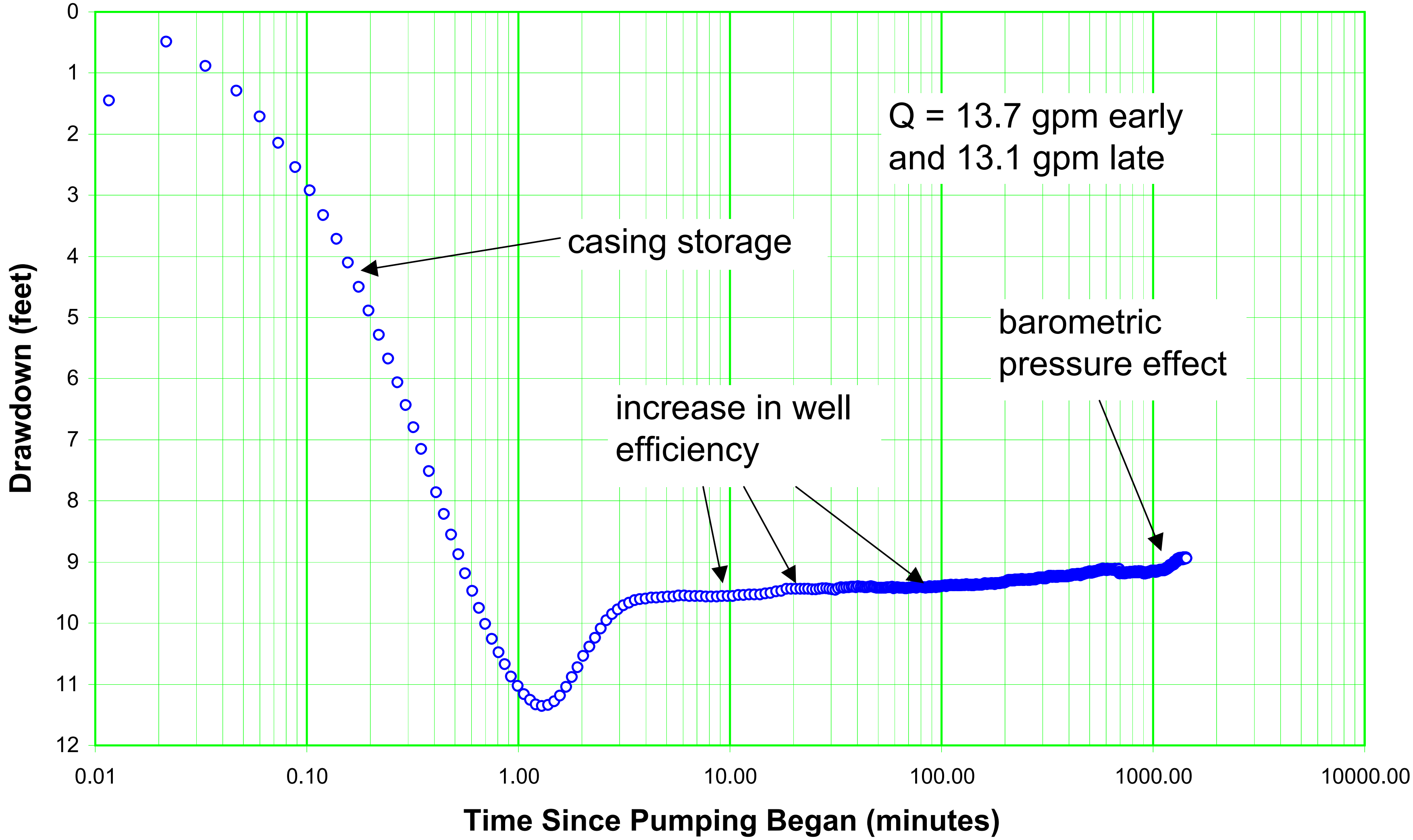


Figure 3. Well R-4 Recovery - Test 1

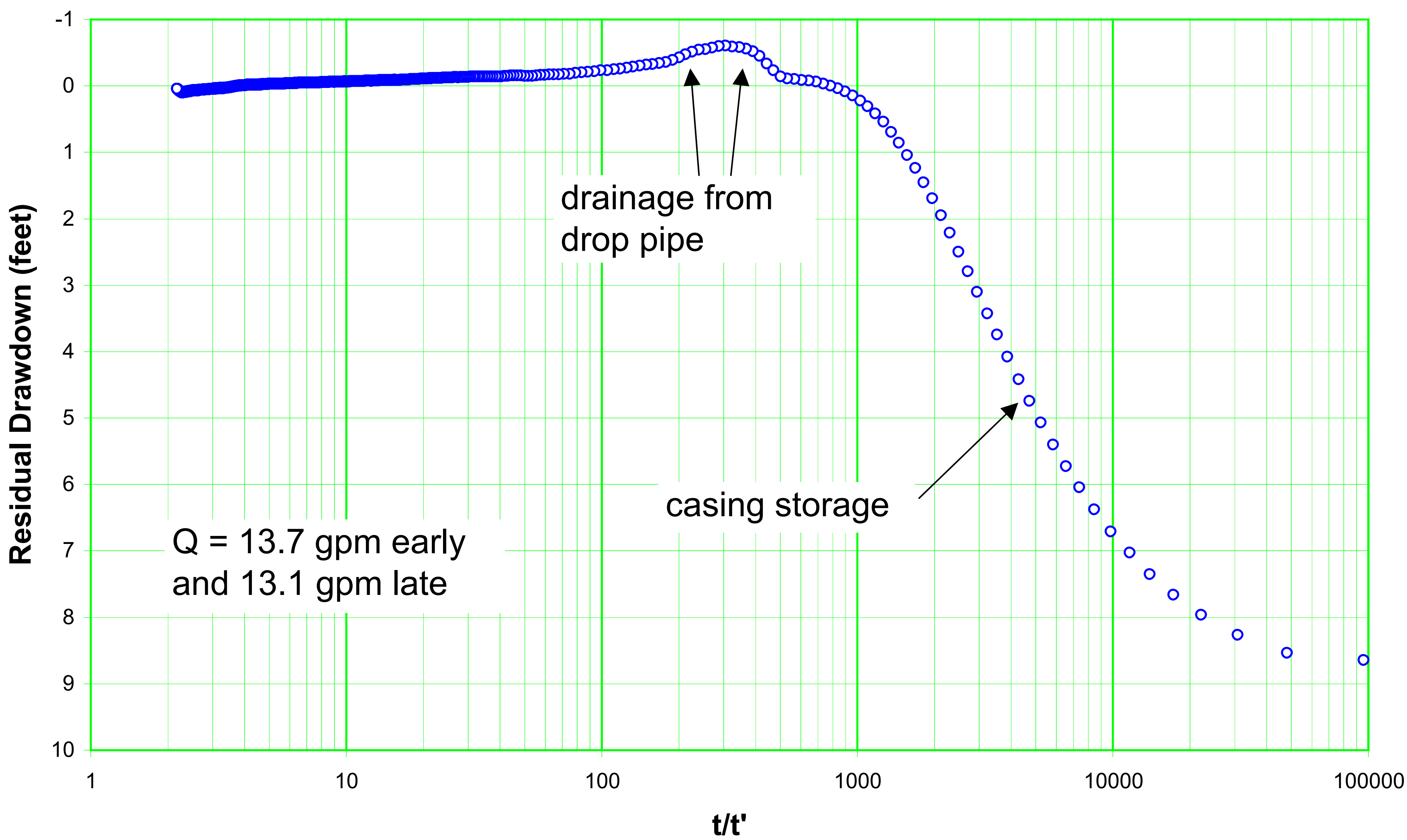


Figure 4. Well R-4 Drawdown - Test 2

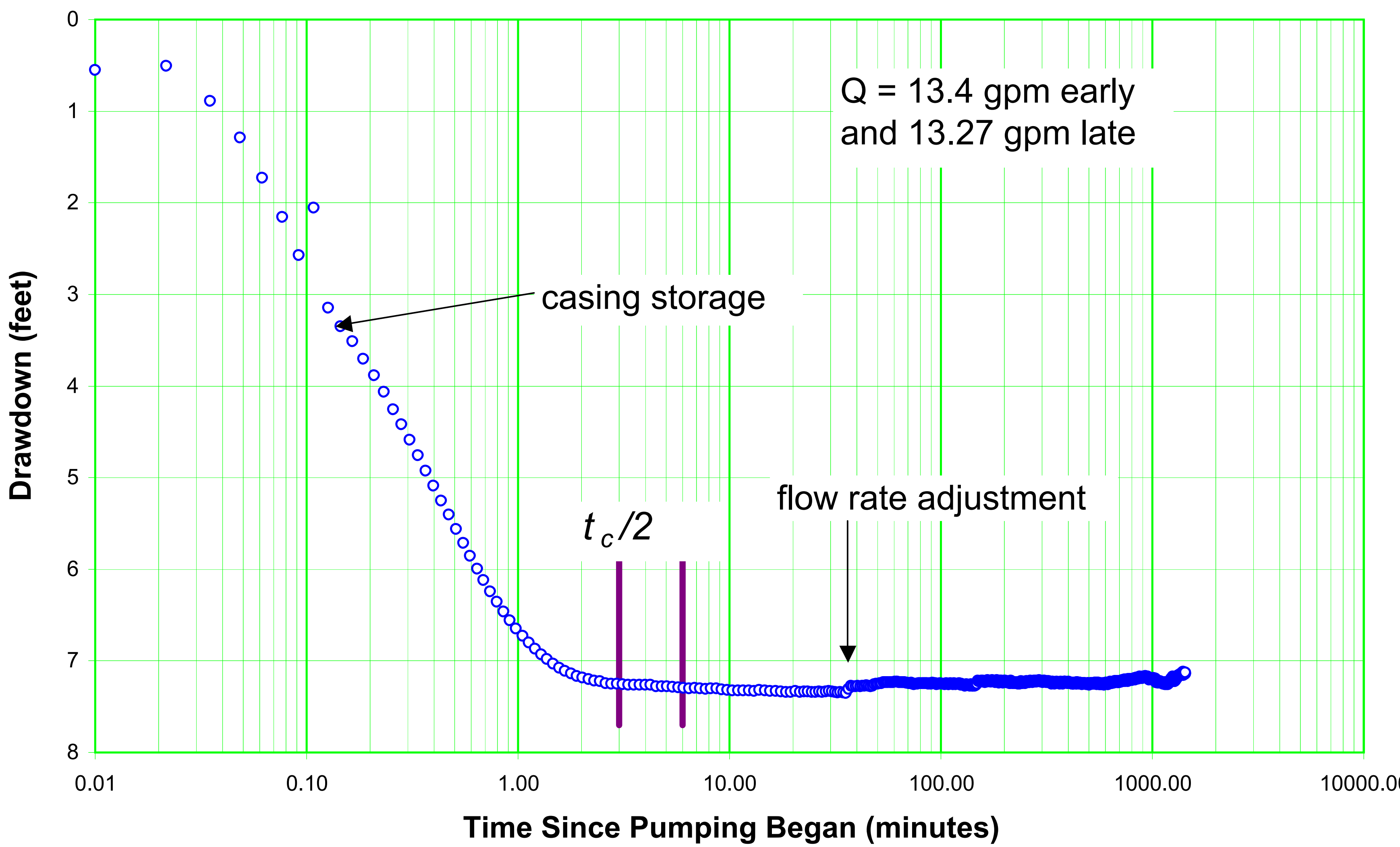


Figure 5. Well R-4 Drawdown Test 2 - Expanded Vertical Scale

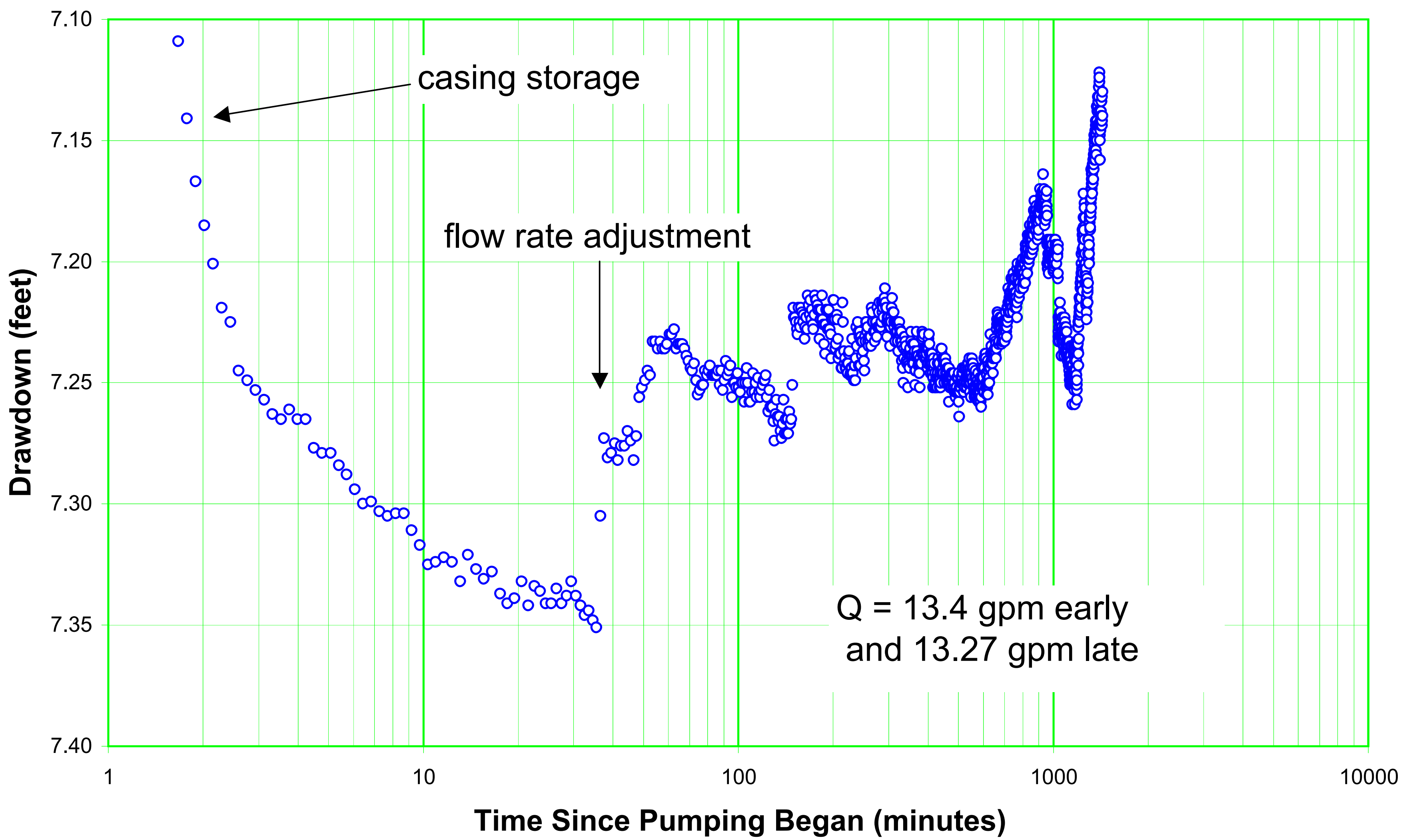


Figure 6. Comparison of Test 2 Pumping Water Levels and Barometric Pressure

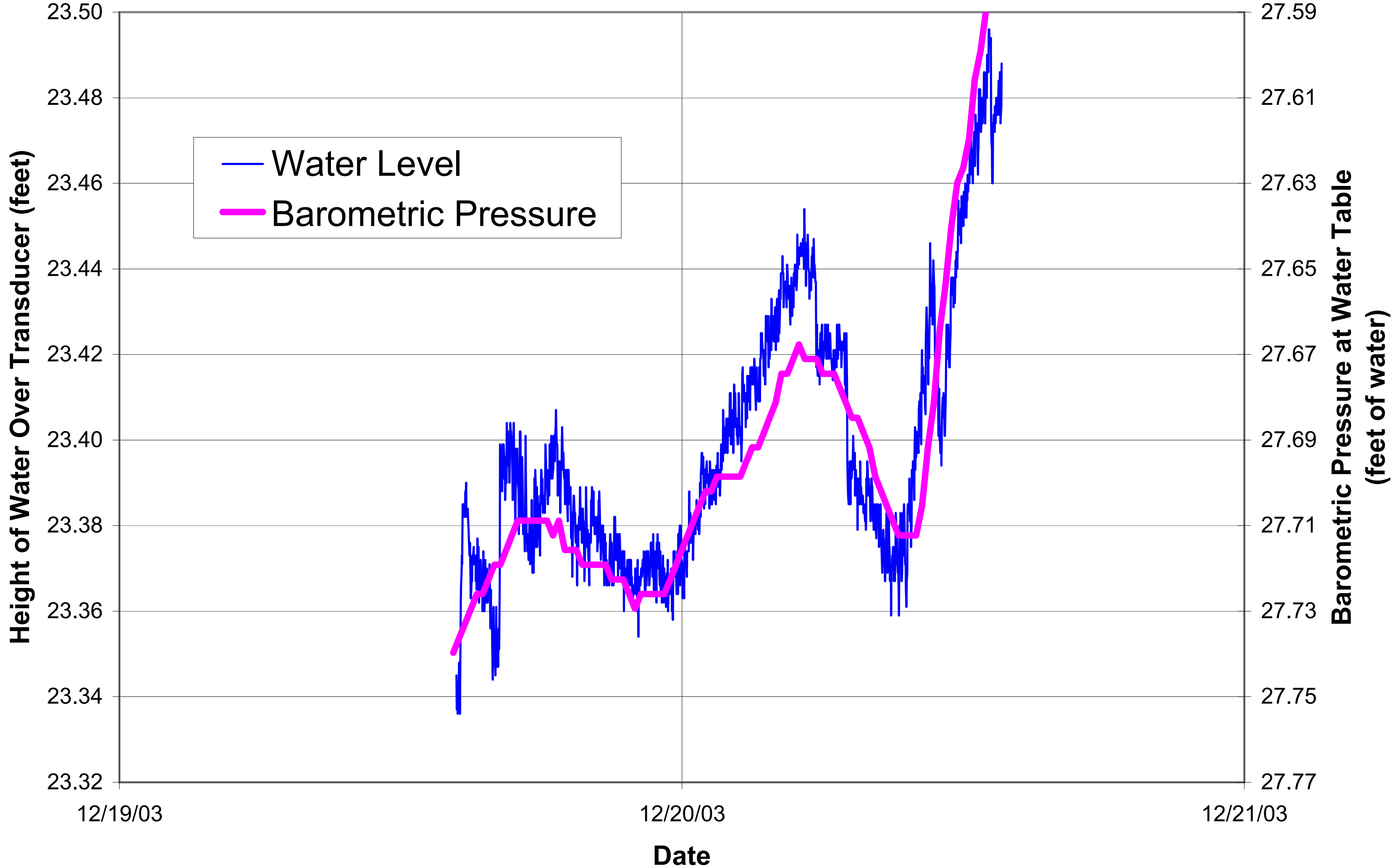


Figure 7. Well R-4 Drawdown - Test 2 - Expanded Horizontal and Vertical Scale

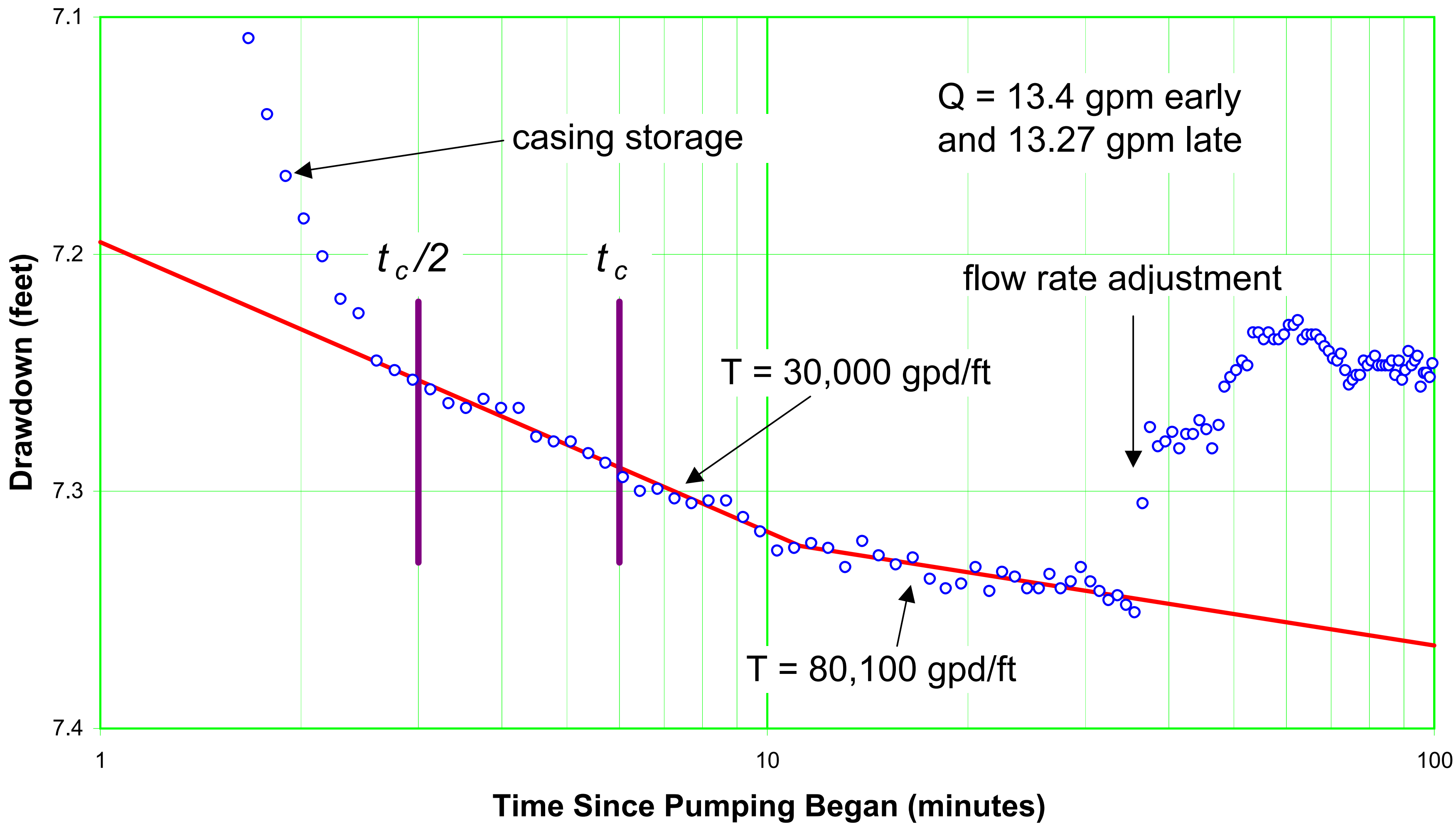


Figure 8. Well R-4 Recovery - Test 2

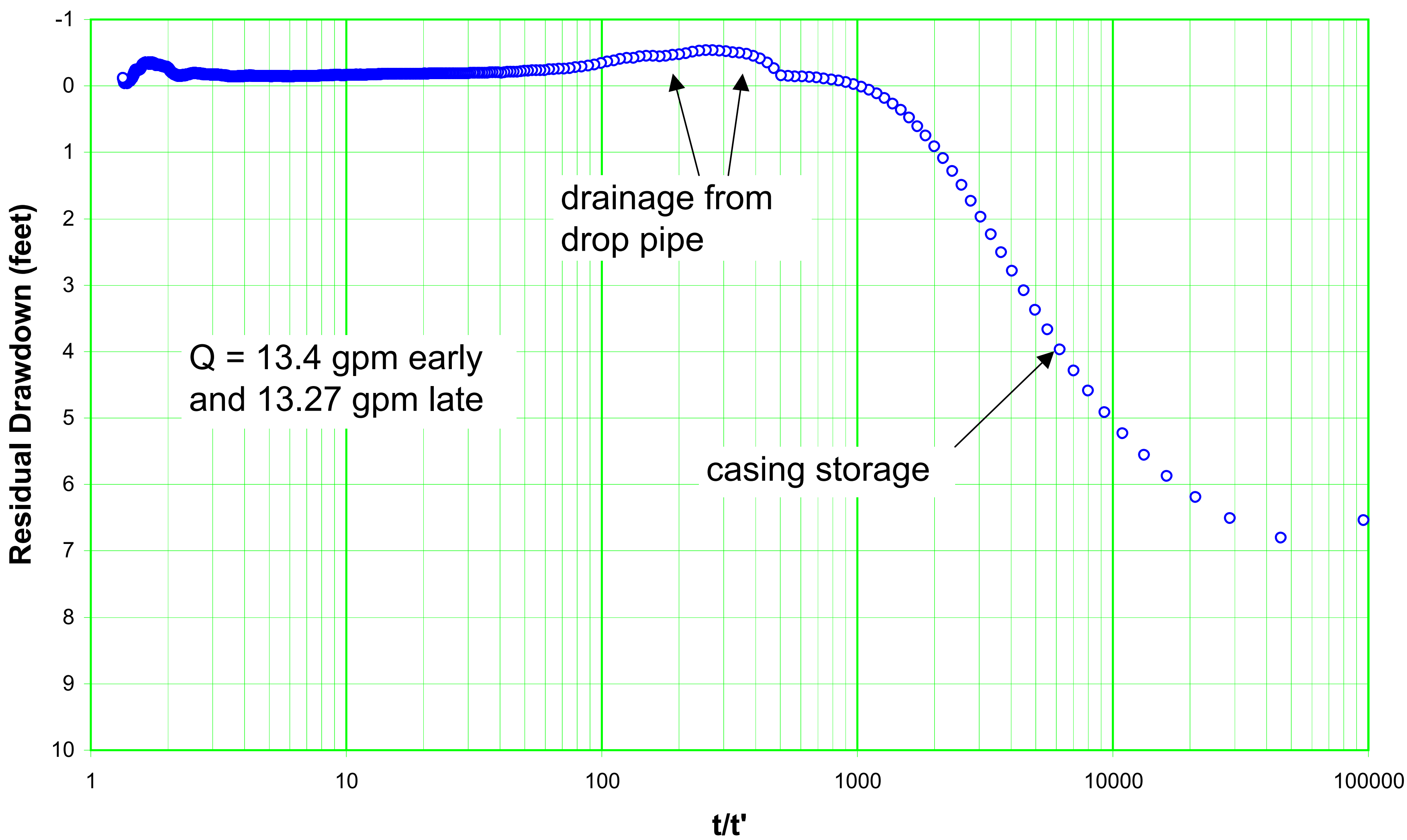


Figure 9. Comparison of R-4 Hydrograph and Barometric Pressure Between Tests 2 and 3

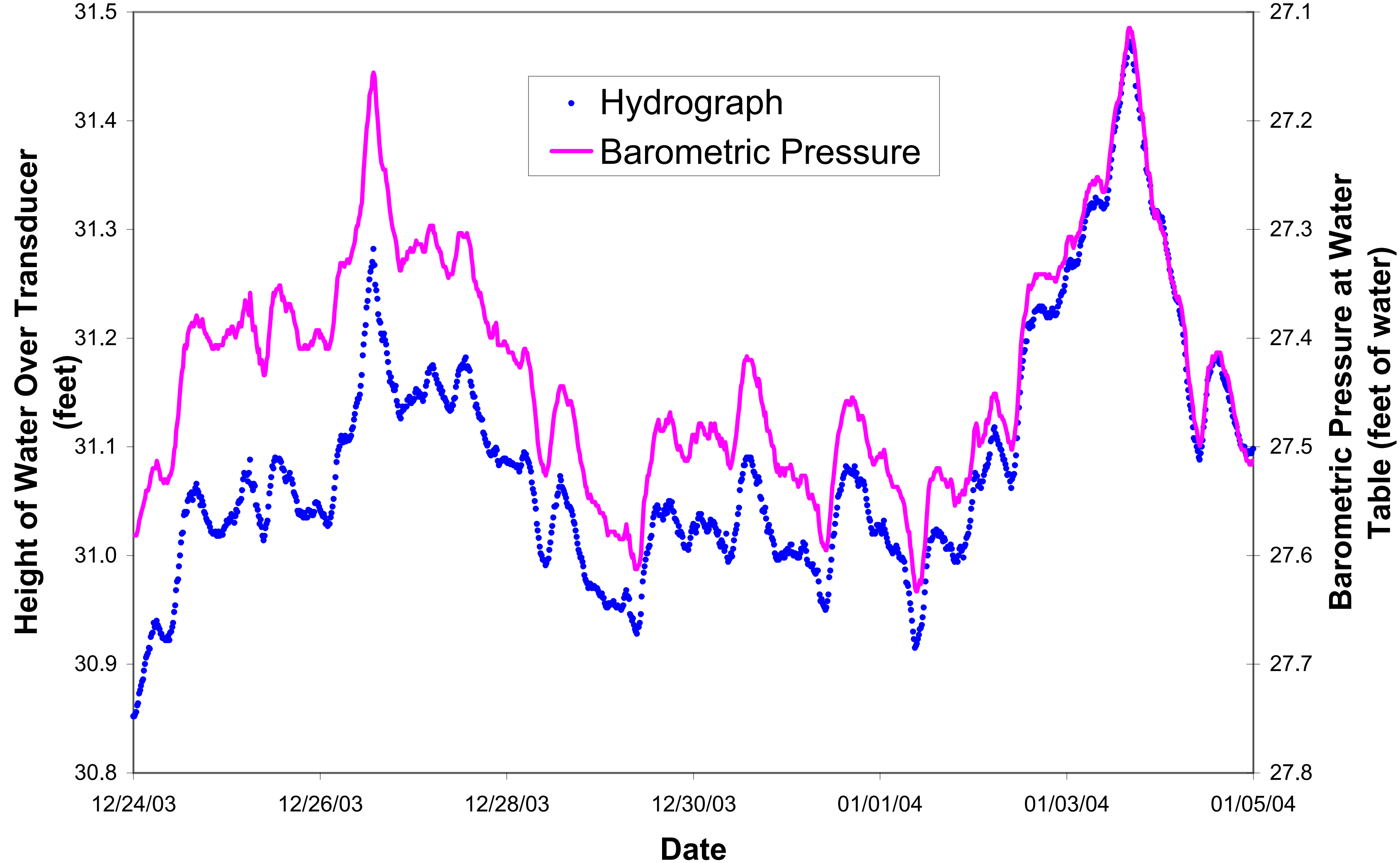


Figure 10. Comparison of R-4 Hydrograph Including Background Trend and Corrected Barometric Pressure Change

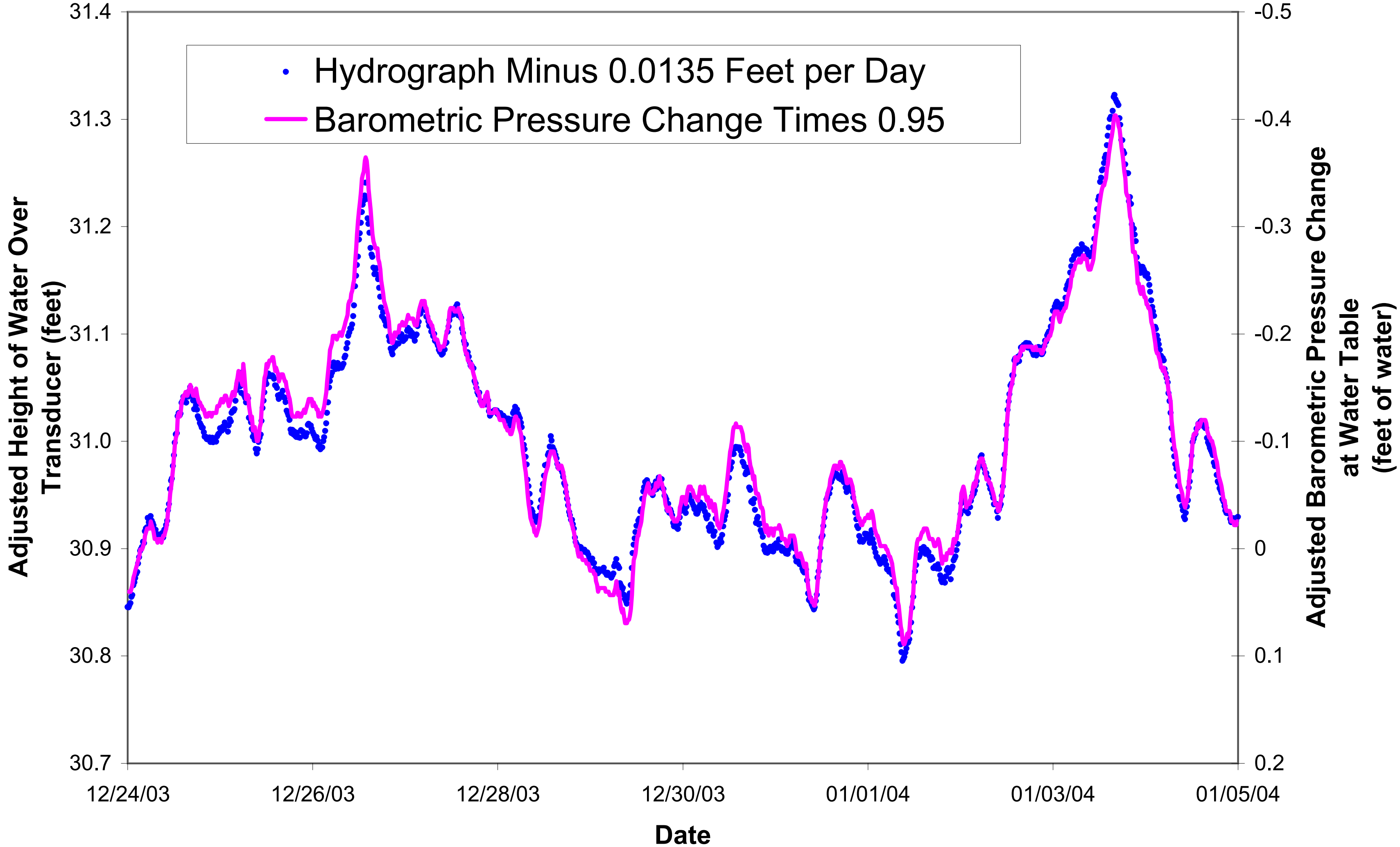


Figure 11. Comparison Adjusted TA-54 Barometric Pressure and BaroTROLL Readings at R-4

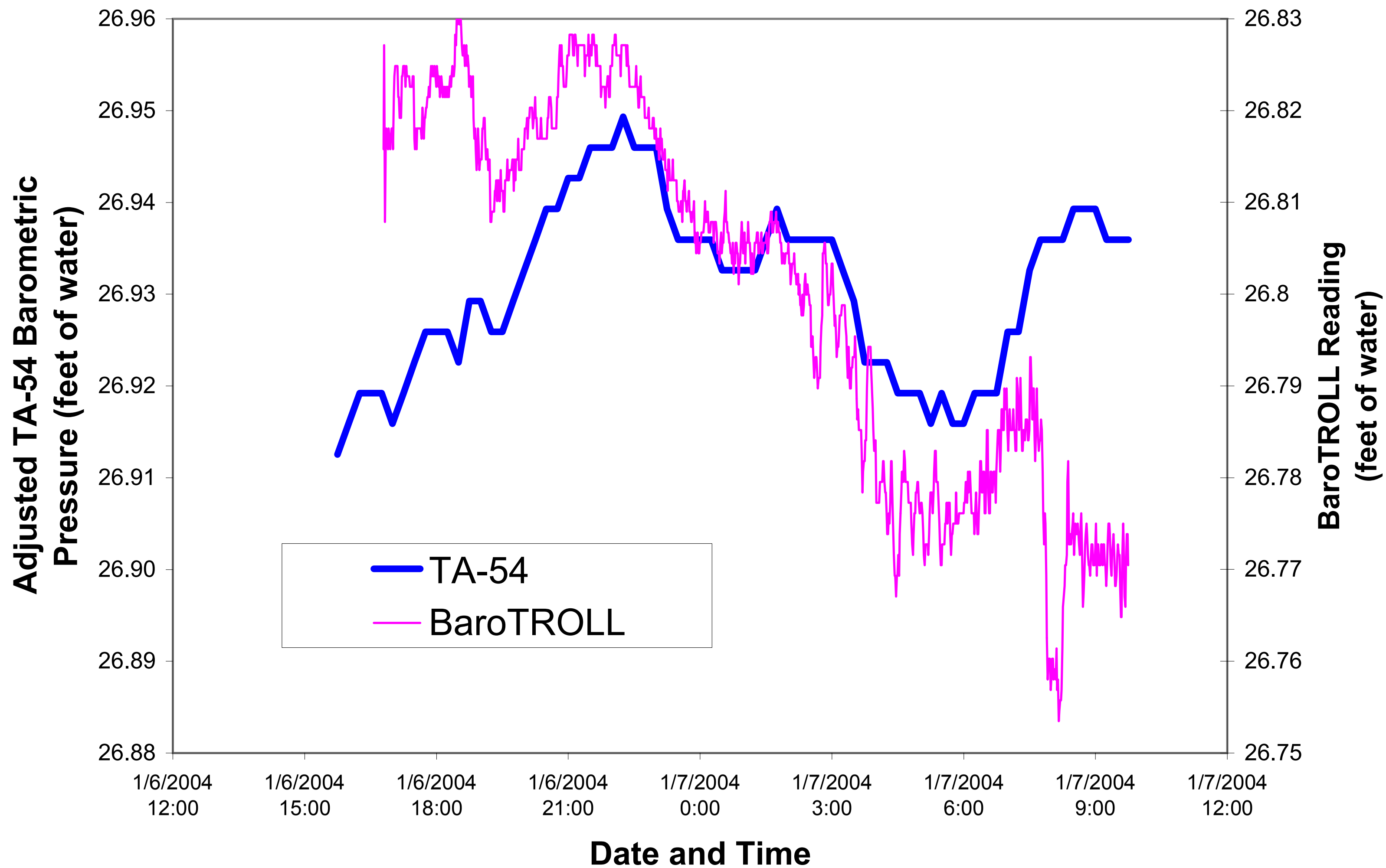


Figure 12. Comparison TA-54 Barometric Pressure and Adjusted BaroTROLL Readings in Los Alamos

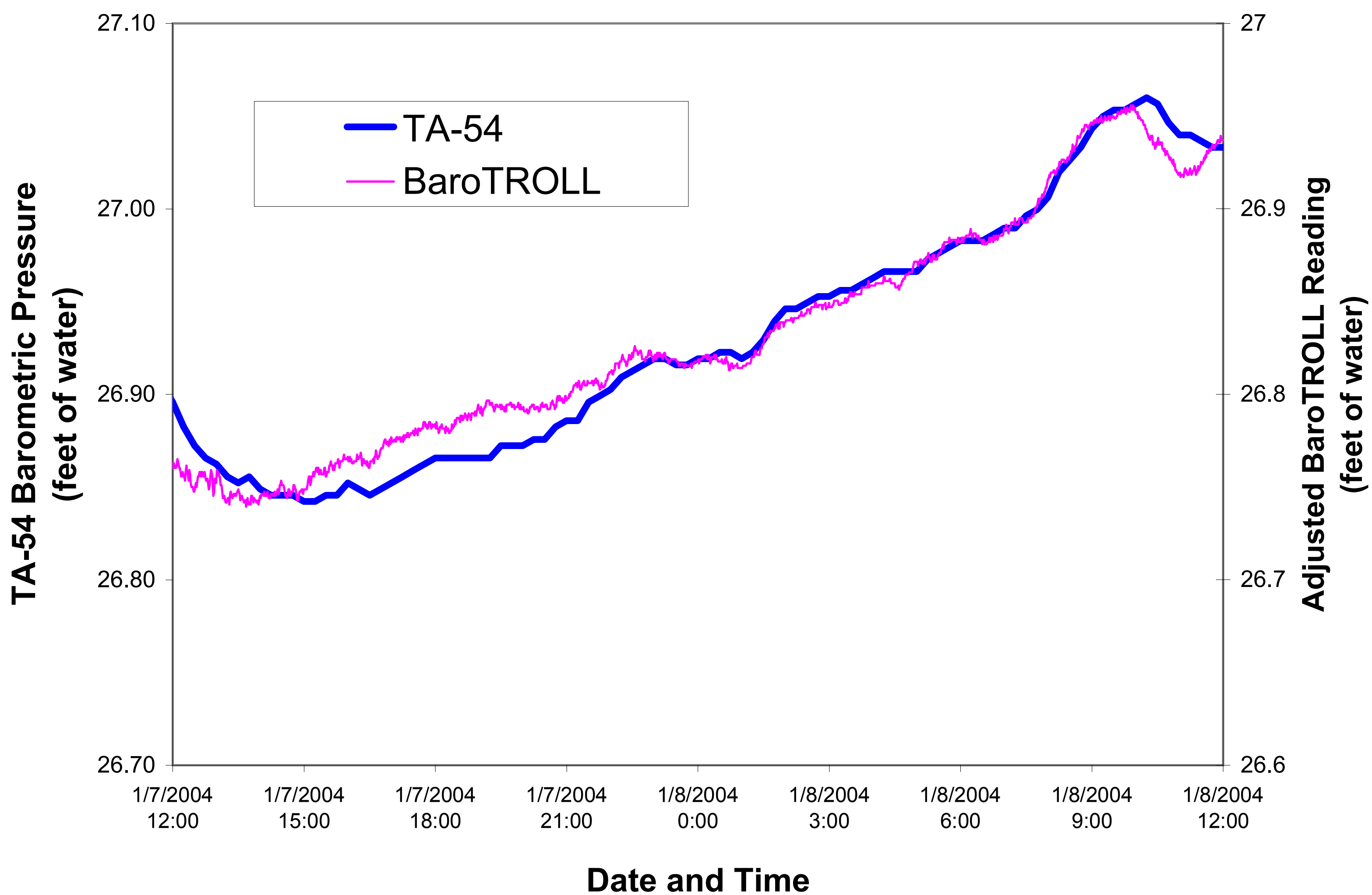


Figure 13. Comparison of R-4 Pretest Hydrograph and Barometric Pressure

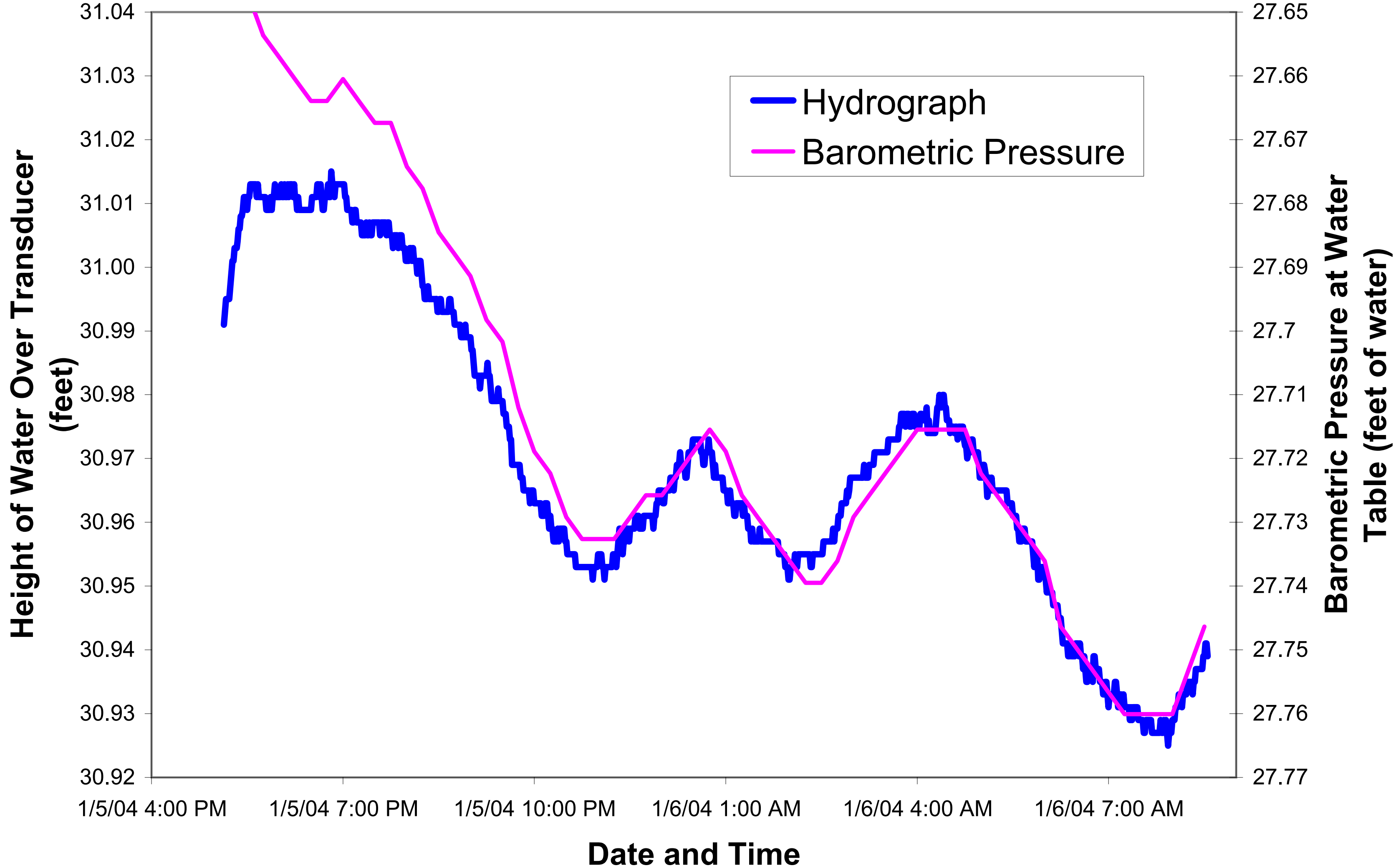


Figure 14. Comparison of R-4 Pretest Hydrograph and Change in Barometric Pressure Adjusted for 95% Barometric Efficiency

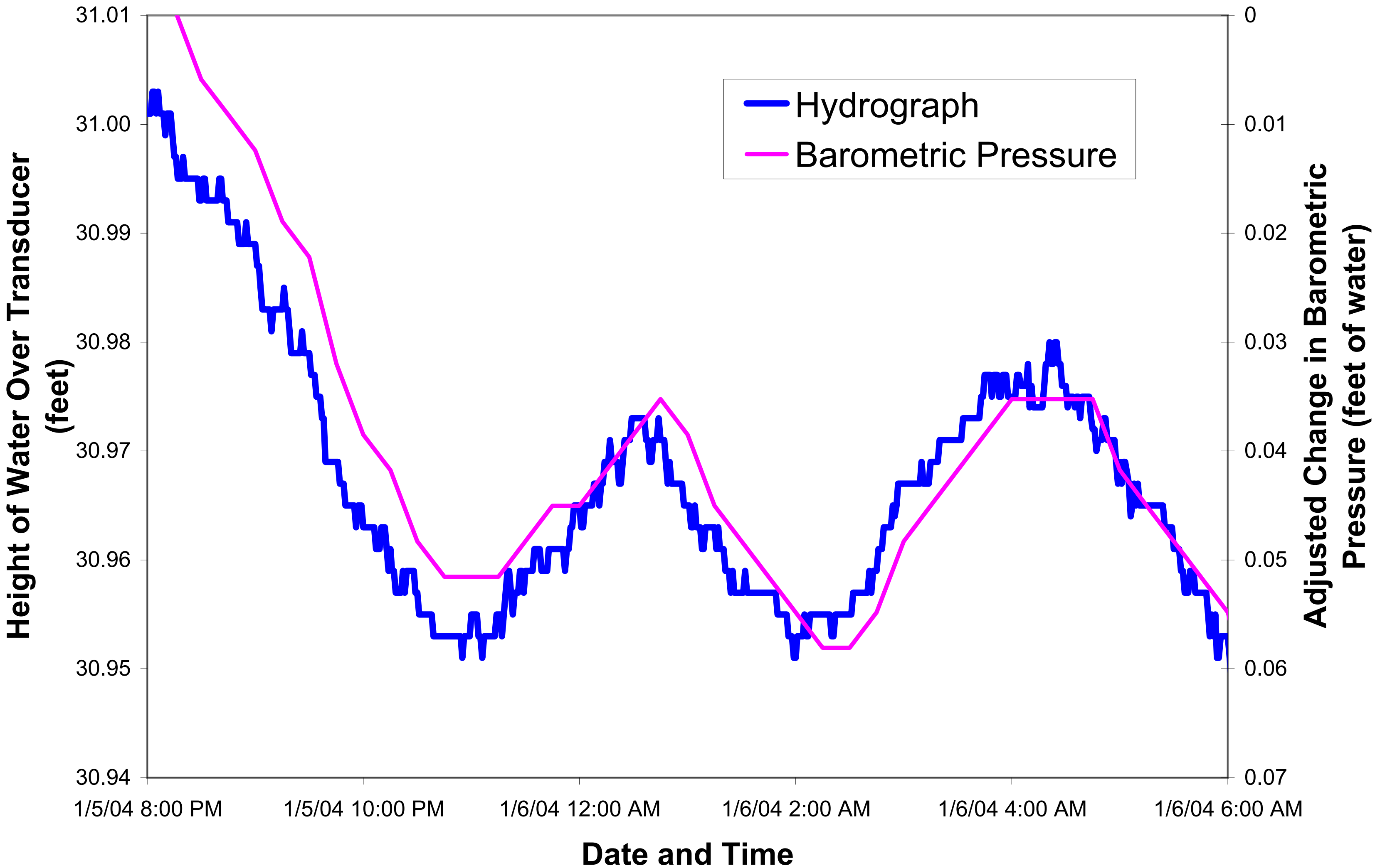


Figure 15. Comparison of R-4 Post-test Hydrograph and Barometric Pressure

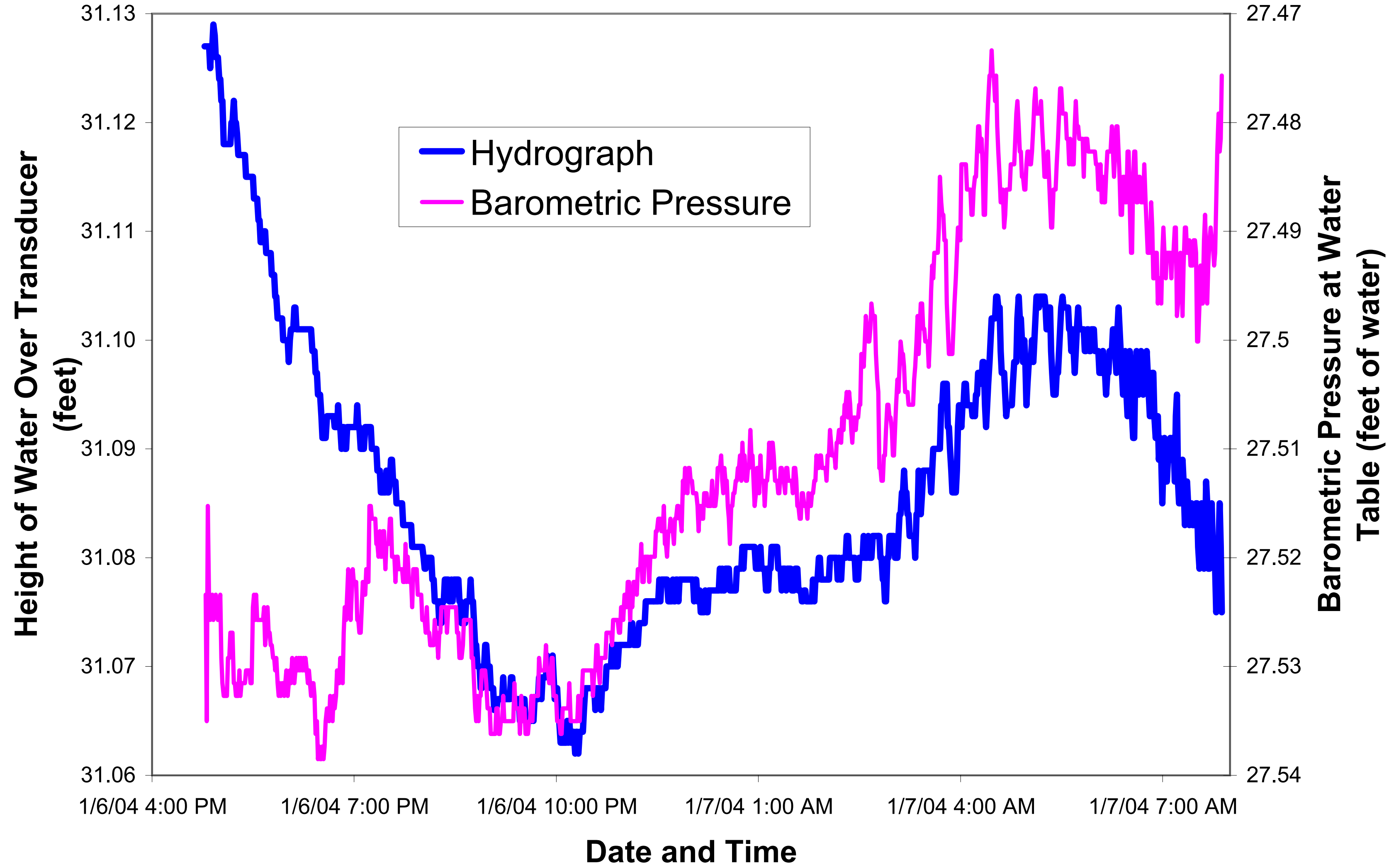


Figure 16. Well R-4 Drawdown - Test 3

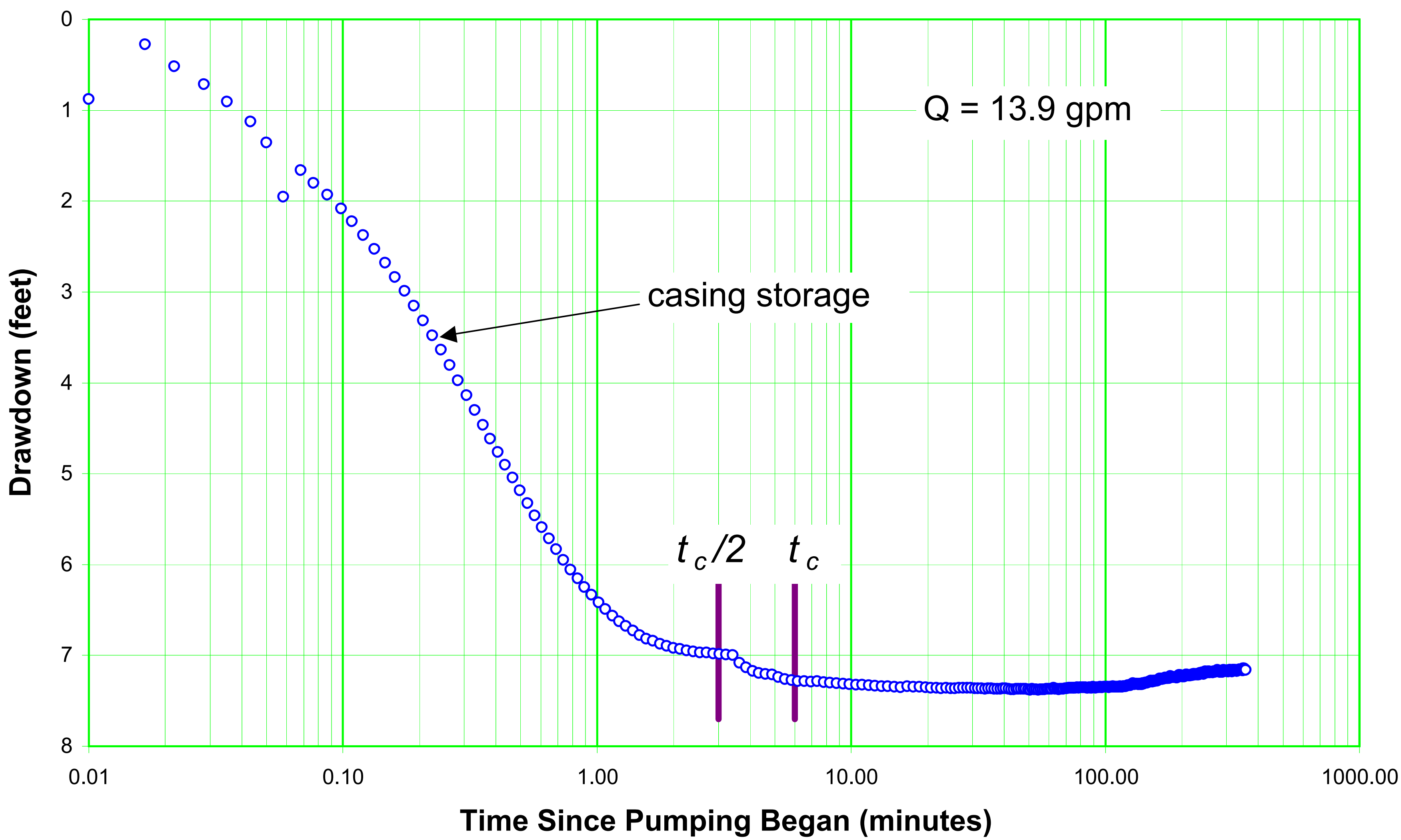


Figure 17. Well R-4 Drawdown - Test 3 - Expanded Scale

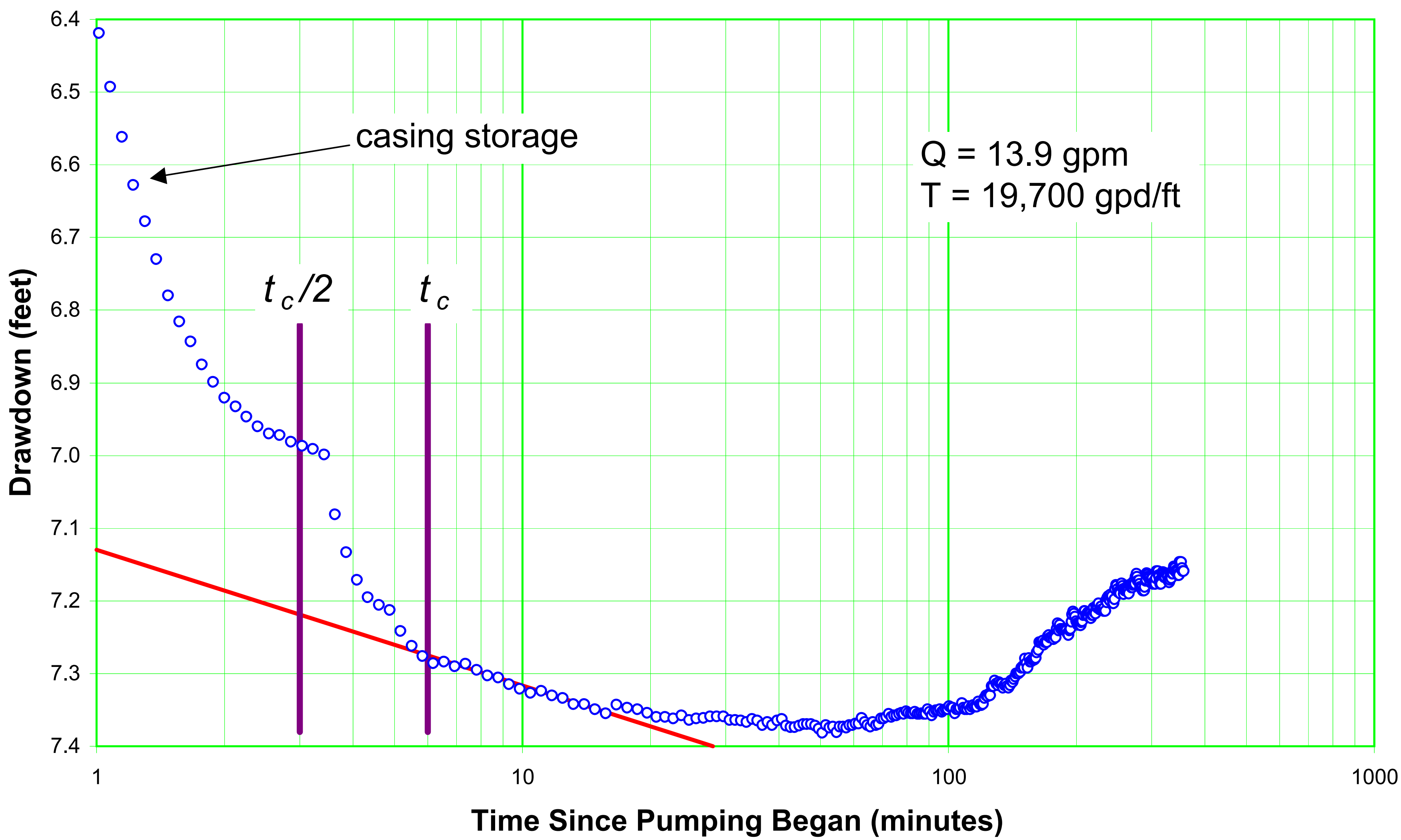


Figure 18. Well R-4 Recovery - Test 3

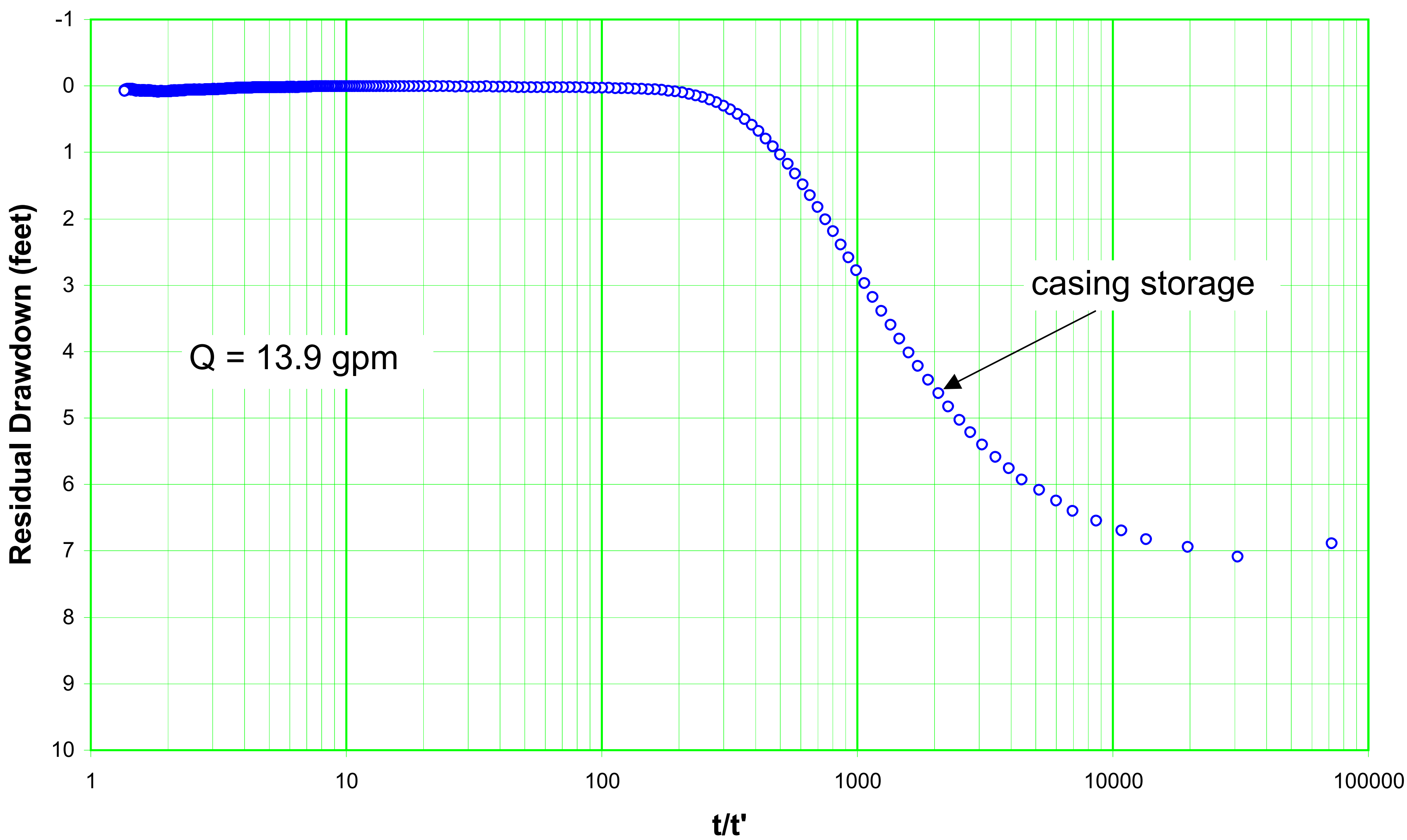


Figure 19. Well R-4 Recovery - Test 3 - Expanded Scale

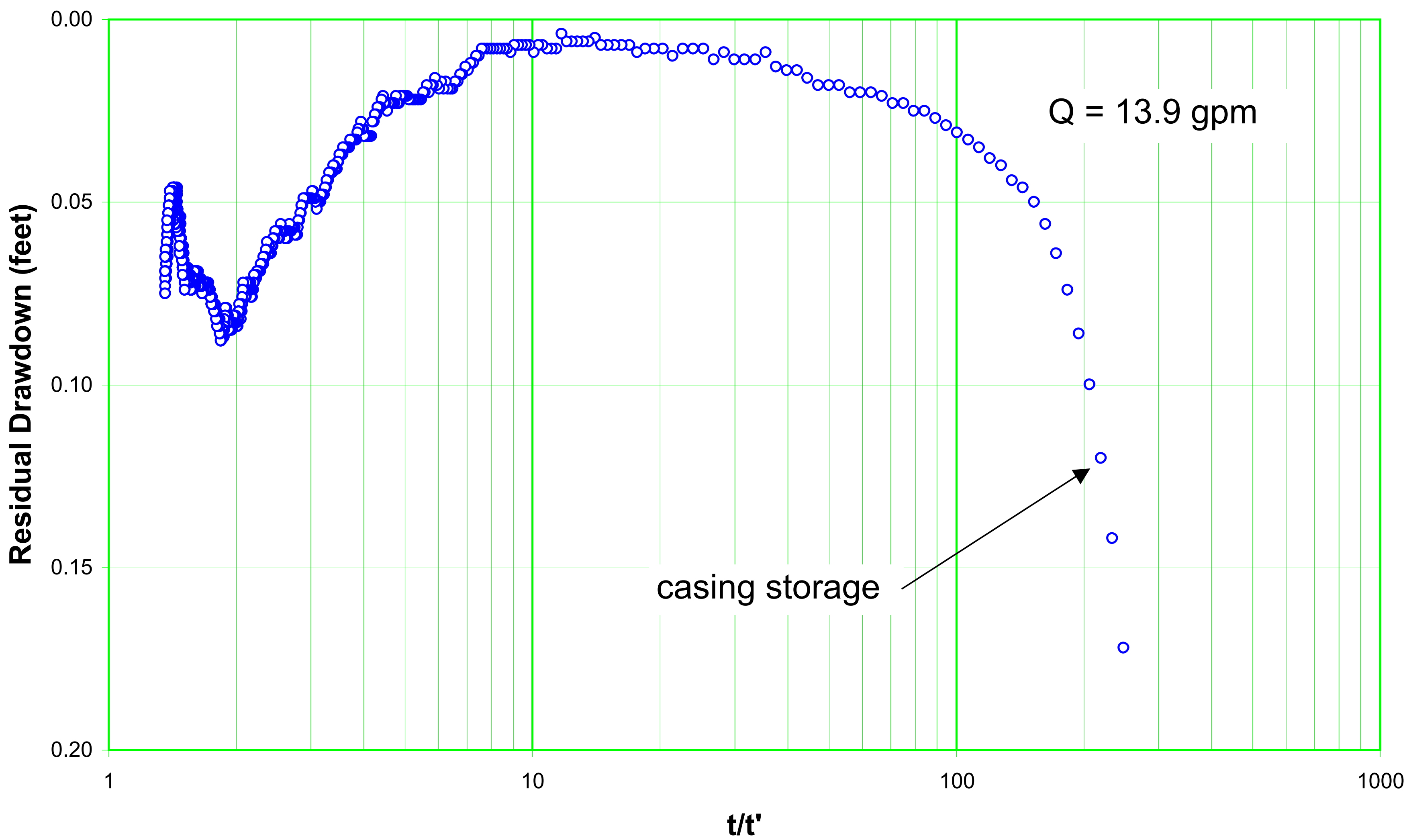
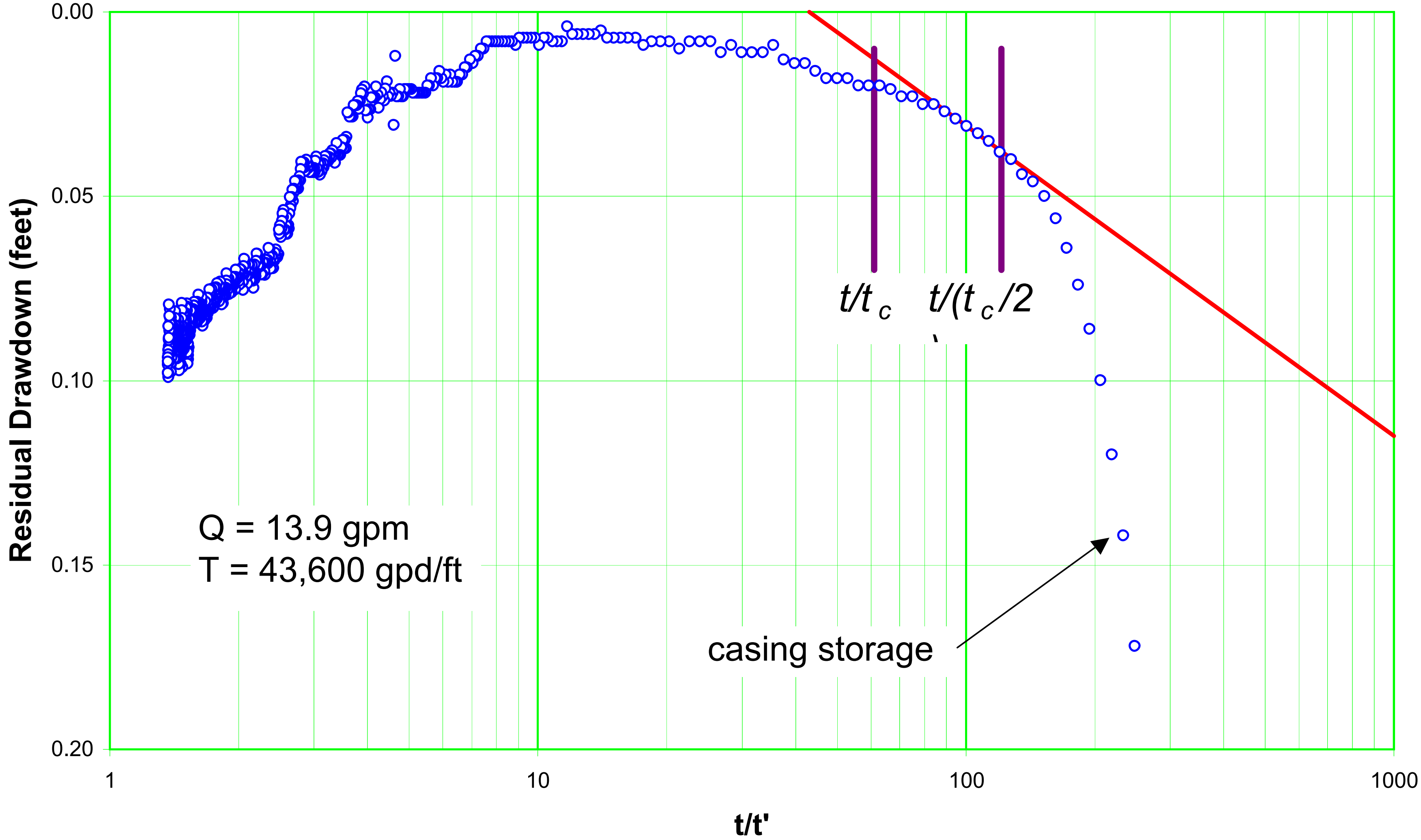


Figure 20. Well R-4 Recovery Corrected For Barometric Pressure



Hall Environmental Analysis Laboratory

COVER LETTER

November 05, 2003

Mark Everett
Kleinfelder
8300 Jefferson, NE Suite B
Albuquerque, NM 87113
TEL: (505) 344-7373
FAX (505) 344-1711

RE: R-4 Characterization Well Order No.: 0310142

Dear Mark Everett:

Hall Environmental Analysis Laboratory received 3 samples on 10/20/2003 for the analyses presented in the following report.

These were analyzed according to EPA procedures or equivalent.

Reporting limits are determined by EPA methodology. No determination of compounds below these (denoted by the ND or < sign) has been made.

Please don't hesitate to contact HEAL for any additional information or clarifications.

Sincerely,

Andy Freeman, Business Manager
Nancy McDuffie, Laboratory Manager

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT: Kleinfelder
Project: R-4 Characterization Well
Lab Order: 0310142

CASE NARRATIVE

Analytical Comments for METHOD 8260_W, SAMPLES 0310142-01a, -02a: Necessary sample dilution due to the foamy nature of the sample.

Analytical Comments for METHOD 8082_W, SAMPLE 0310142-01B: Low surrogate recovery due to heavy emulsion formed during sample extraction. Analytical Comments for METHOD 8082_W, SAMPLE 0310142-02B: Low surrogate recovery due to heavy emulsion formed during sample extraction.

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Tank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:30:00 PM
Lab ID:	0310142-01A	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 8260B: VOLATILES						Analyst: **JDC**
Benzene	ND	100		µg/L	100	10/21/2003
Toluene	ND	100		µg/L	100	10/21/2003
Ethylbenzene	ND	100		µg/L	100	10/21/2003
Methyl tert-butyl ether (MTBE)	ND	100		µg/L	100	10/21/2003
1,2,4-Trimethylbenzene	ND	100		µg/L	100	10/21/2003
1,3,5-Trimethylbenzene	ND	100		µg/L	100	10/21/2003
1,2-Dichloroethane (EDC)	ND	100		µg/L	100	10/21/2003
1,2-Dibromoethane (EDB)	ND	100		µg/L	100	10/21/2003
Naphthalene	ND	200		µg/L	100	10/21/2003
1-Methylnaphthalene	ND	400		µg/L	100	10/21/2003
2-Methylnaphthalene	ND	400		µg/L	100	10/21/2003
Acetone	3100	1000		µg/L	100	10/21/2003
Bromobenzene	ND	100		µg/L	100	10/21/2003
Bromochloromethane	ND	100		µg/L	100	10/21/2003
Bromodichloromethane	ND	100		µg/L	100	10/21/2003
Bromoform	ND	100		µg/L	100	10/21/2003
Bromomethane	ND	200		µg/L	100	10/21/2003
2-Butanone	ND	1000		µg/L	100	10/21/2003
Carbon disulfide	ND	1000		µg/L	100	10/21/2003
Carbon Tetrachloride	ND	100		µg/L	100	10/21/2003
Chlorobenzene	ND	100		µg/L	100	10/21/2003
Chloroethane	ND	200		µg/L	100	10/21/2003
Chloroform	ND	100		µg/L	100	10/21/2003
Chloromethane	ND	100		µg/L	100	10/21/2003
2-Chlorotoluene	ND	100		µg/L	100	10/21/2003
4-Chlorotoluene	ND	100		µg/L	100	10/21/2003
cis-1,2-DCE	ND	100		µg/L	100	10/21/2003
cis-1,3-Dichloropropene	ND	100		µg/L	100	10/21/2003
1,2-Dibromo-3-chloropropane	ND	200		µg/L	100	10/21/2003
Dibromochloromethane	ND	100		µg/L	100	10/21/2003
Dibromomethane	ND	200		µg/L	100	10/21/2003
1,2-Dichlorobenzene	ND	100		µg/L	100	10/21/2003
1,3-Dichlorobenzene	ND	100		µg/L	100	10/21/2003
1,4-Dichlorobenzene	ND	100		µg/L	100	10/21/2003
Dichlorodifluoromethane	ND	100		µg/L	100	10/21/2003
1,1-Dichloroethane	ND	100		µg/L	100	10/21/2003
1,1-Dichloroethene	ND	100		µg/L	100	10/21/2003
1,2-Dichloropropane	ND	100		µg/L	100	10/21/2003
1,3-Dichloropropane	ND	100		µg/L	100	10/21/2003
2,2-Dichloropropane	ND	100		µg/L	100	10/21/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Tank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:30:00 PM
Lab ID:	0310142-01A	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
1,1-Dichloropropene	ND	100		µg/L	100	10/21/2003
Hexachlorobutadiene	ND	100		µg/L	100	10/21/2003
2-Hexanone	ND	1000		µg/L	100	10/21/2003
Isopropylbenzene	ND	100		µg/L	100	10/21/2003
4-Isopropyltoluene	ND	100		µg/L	100	10/21/2003
4-Methyl-2-pentanone	ND	1000		µg/L	100	10/21/2003
Methylene Chloride	ND	300		µg/L	100	10/21/2003
n-Butylbenzene	ND	100		µg/L	100	10/21/2003
n-Propylbenzene	ND	100		µg/L	100	10/21/2003
sec-Butylbenzene	ND	100		µg/L	100	10/21/2003
Styrene	ND	100		µg/L	100	10/21/2003
tert-Butylbenzene	ND	100		µg/L	100	10/21/2003
1,1,1,2-Tetrachloroethane	ND	100		µg/L	100	10/21/2003
1,1,2,2-Tetrachloroethane	ND	100		µg/L	100	10/21/2003
Tetrachloroethene (PCE)	ND	100		µg/L	100	10/21/2003
trans-1,2-DCE	ND	100		µg/L	100	10/21/2003
trans-1,3-Dichloropropene	ND	100		µg/L	100	10/21/2003
1,2,3-Trichlorobenzene	ND	100		µg/L	100	10/21/2003
1,2,4-Trichlorobenzene	ND	100		µg/L	100	10/21/2003
1,1,1-Trichloroethane	ND	100		µg/L	100	10/21/2003
1,1,2-Trichloroethane	ND	100		µg/L	100	10/21/2003
Trichloroethene (TCE)	ND	100		µg/L	100	10/21/2003
Trichlorofluoromethane	ND	100		µg/L	100	10/21/2003
1,2,3-Trichloropropane	ND	200		µg/L	100	10/21/2003
Vinyl chloride	ND	200		µg/L	100	10/21/2003
Xylenes, Total	ND	100		µg/L	100	10/21/2003
Surr: 1,2-Dichloroethane-d4	91.9	70.6-124		%REC	100	10/21/2003
Surr: 4-Bromofluorobenzene	95.1	76.2-122		%REC	100	10/21/2003
Surr: Dibromofluoromethane	94.4	67.2-131		%REC	100	10/21/2003
Surr: Toluene-d8	104	82.1-123		%REC	100	10/21/2003

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Tank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:30:00 AM
Lab ID:	0310142-01B	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 8082: PCB'S						Analyst: **GT**
Aroclor 1016	ND	10		µg/L	1	11/4/2003 12:47:57 AM
Aroclor 1221	ND	50		µg/L	1	11/4/2003 12:47:57 AM
Aroclor 1232	ND	10		µg/L	1	11/4/2003 12:47:57 AM
Aroclor 1242	ND	10		µg/L	1	11/4/2003 12:47:57 AM
Aroclor 1248	ND	10		µg/L	1	11/4/2003 12:47:57 AM
Aroclor 1254	ND	10		µg/L	1	11/4/2003 12:47:57 AM
Aroclor 1260	ND	10		µg/L	1	11/4/2003 12:47:57 AM
Surr: Decachlorobiphenyl	34.8	76-111	S	%REC	1	11/4/2003 12:47:57 AM
Surr: Tetrachloro-m-xylene	48.4	47-94		%REC	1	11/4/2003 12:47:57 AM
EPA METHOD 8270D: SEMIVOLATILES						Analyst: **CS**
Acenaphthene	ND	50		µg/L	1	10/4/2003
Acenaphthylene	ND	50		µg/L	1	10/4/2003
Aniline	ND	50		µg/L	1	10/4/2003
Anthracene	ND	50		µg/L	1	10/4/2003
Azobenzene	ND	50		µg/L	1	10/4/2003
Benz(a)anthracene	ND	50		µg/L	1	10/4/2003
Benzidine	ND	100		µg/L	1	10/4/2003
Benzo(a)pyrene	ND	50		µg/L	1	10/4/2003
Benzo(b)fluoranthene	ND	50		µg/L	1	10/4/2003
Benzo(g,h,i)perylene	ND	50		µg/L	1	10/4/2003
Benzo(k)fluoranthene	ND	50		µg/L	1	10/4/2003
Benzoic acid	ND	250		µg/L	1	10/4/2003
Benzyl alcohol	ND	100		µg/L	1	10/4/2003
Bis(2-chloroethoxy)methane	ND	50		µg/L	1	10/4/2003
Bis(2-chloroethyl)ether	ND	50		µg/L	1	10/4/2003
Bis(2-chloroisopropyl)ether	ND	50		µg/L	1	10/4/2003
Bis(2-ethylhexyl)phthalate	94	50		µg/L	1	10/4/2003
4-Bromophenyl phenyl ether	ND	50		µg/L	1	10/4/2003
Butyl benzyl phthalate	ND	50		µg/L	1	10/4/2003
Carbazole	ND	50		µg/L	1	10/4/2003
4-Chloro-3-methylphenol	ND	100		µg/L	1	10/4/2003
4-Chloroaniline	ND	100		µg/L	1	10/4/2003
2-Chloronaphthalene	ND	50		µg/L	1	10/4/2003
2-Chlorophenol	ND	50		µg/L	1	10/4/2003
4-Chlorophenyl phenyl ether	ND	50		µg/L	1	10/4/2003
Chrysene	ND	50		µg/L	1	10/4/2003
Di-n-butyl phthalate	53	50		µg/L	1	10/4/2003
Di-n-octyl phthalate	ND	50		µg/L	1	10/4/2003
Dibenz(a,h)anthracene	ND	50		µg/L	1	10/4/2003
Dibenzofuran	ND	50		µg/L	1	10/4/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Tank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:30:00 AM
Lab ID:	0310142-01B	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
1,2-Dichlorobenzene	ND	50		µg/L	1	10/4/2003
1,3-Dichlorobenzene	ND	50		µg/L	1	10/4/2003
1,4-Dichlorobenzene	ND	50		µg/L	1	10/4/2003
3,3'-Dichlorobenzidine	ND	50		µg/L	1	10/4/2003
Diethyl phthalate	ND	50		µg/L	1	10/4/2003
Dimethyl phthalate	ND	50		µg/L	1	10/4/2003
2,4-Dichlorophenol	ND	50		µg/L	1	10/4/2003
2,4-Dimethylphenol	ND	50		µg/L	1	10/4/2003
4,6-Dinitro-2-methylphenol	ND	250		µg/L	1	10/4/2003
2,4-Dinitrophenol	ND	250		µg/L	1	10/4/2003
2,4-Dinitrotoluene	ND	50		µg/L	1	10/4/2003
2,6-Dinitrotoluene	ND	50		µg/L	1	10/4/2003
Fluoranthene	ND	50		µg/L	1	10/4/2003
Fluorene	ND	50		µg/L	1	10/4/2003
Hexachlorobenzene	ND	50		µg/L	1	10/4/2003
Hexachlorobutadiene	ND	50		µg/L	1	10/4/2003
Hexachlorocyclopentadiene	ND	50		µg/L	1	10/4/2003
Hexachloroethane	ND	50		µg/L	1	10/4/2003
Indeno(1,2,3-cd)pyrene	ND	50		µg/L	1	10/4/2003
Isophorone	ND	50		µg/L	1	10/4/2003
2-Methylnaphthalene	ND	50		µg/L	1	10/4/2003
2-Methylphenol	ND	50		µg/L	1	10/4/2003
3+4-Methylphenol	ND	50		µg/L	1	10/4/2003
N-Nitrosodi-n-propylamine	ND	50		µg/L	1	10/4/2003
N-Nitrosodiphenylamine	ND	50		µg/L	1	10/4/2003
Naphthalene	ND	50		µg/L	1	10/4/2003
2-Nitroaniline	ND	250		µg/L	1	10/4/2003
3-Nitroaniline	ND	250		µg/L	1	10/4/2003
4-Nitroaniline	ND	100		µg/L	1	10/4/2003
Nitrobenzene	ND	50		µg/L	1	10/4/2003
2-Nitrophenol	ND	50		µg/L	1	10/4/2003
4-Nitrophenol	ND	250		µg/L	1	10/4/2003
Pentachlorophenol	ND	250		µg/L	1	10/4/2003
Phenanthrene	ND	50		µg/L	1	10/4/2003
Phenol	ND	50		µg/L	1	10/4/2003
Pyrene	ND	50		µg/L	1	10/4/2003
Pyridine	ND	50		µg/L	1	10/4/2003
1,2,4-Trichlorobenzene	ND	50		µg/L	1	10/4/2003
2,4,5-Trichlorophenol	ND	50		µg/L	1	10/4/2003
2,4,6-Trichlorophenol	ND	50		µg/L	1	10/4/2003
Surr: 2,4,6-Tribromophenol	1.71	16.6-115	S	%REC	1	10/4/2003
Surr: 2-Fluorobiphenyl	81.4	37-95.7		%REC	1	10/4/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Tank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:30:00 AM
Lab ID:	0310142-01B	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
Surr: 2-Fluorophenol	1.28	9.54-89.8	S	%REC	1	10/4/2003
Surr: 4-Terphenyl-d14	65.5	47.9-115		%REC	1	10/4/2003
Surr: Nitrobenzene-d5	74.7	38-106		%REC	1	10/4/2003
Surr: Phenol-d6	0	10.7-63.4	S	%REC	1	10/4/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Tank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:30:00 PM
Lab ID:	0310142-01C	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 300.0: ANIONS						Analyst: **BL**
Fluoride	1.1	0.10		mg/L	1	10/21/2003 10:45:27 AM
Chloride	21	0.10		mg/L	1	10/21/2003 10:45:27 AM
Nitrogen, Nitrite (As N)	ND	0.10		mg/L	1	10/21/2003 10:45:27 AM
Nitrogen, Nitrate (As N)	ND	0.10		mg/L	1	10/21/2003 10:45:27 AM
Phosphorus, Orthophosphate (As P)	ND	0.50		mg/L	1	10/21/2003 10:45:27 AM
Sulfate	330	5.0		mg/L	10	10/21/2003 12:34:52 PM

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Pit
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:00:00 PM
Lab ID:	0310142-02A	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 8260B: VOLATILES						Analyst: **JDC**
Benzene	ND	100		µg/L	100	10/21/2003
Toluene	ND	100		µg/L	100	10/21/2003
Ethylbenzene	ND	100		µg/L	100	10/21/2003
Methyl tert-butyl ether (MTBE)	ND	100		µg/L	100	10/21/2003
1,2,4-Trimethylbenzene	ND	100		µg/L	100	10/21/2003
1,3,5-Trimethylbenzene	ND	100		µg/L	100	10/21/2003
1,2-Dichloroethane (EDC)	ND	100		µg/L	100	10/21/2003
1,2-Dibromoethane (EDB)	ND	100		µg/L	100	10/21/2003
Naphthalene	ND	200		µg/L	100	10/21/2003
1-Methylnaphthalene	ND	400		µg/L	100	10/21/2003
2-Methylnaphthalene	ND	400		µg/L	100	10/21/2003
Acetone	4800	1000		µg/L	100	10/21/2003
Bromobenzene	ND	100		µg/L	100	10/21/2003
Bromochloromethane	ND	100		µg/L	100	10/21/2003
Bromodichloromethane	ND	100		µg/L	100	10/21/2003
Bromoform	ND	100		µg/L	100	10/21/2003
Bromomethane	ND	200		µg/L	100	10/21/2003
2-Butanone	ND	1000		µg/L	100	10/21/2003
Carbon disulfide	ND	1000		µg/L	100	10/21/2003
Carbon Tetrachloride	ND	100		µg/L	100	10/21/2003
Chlorobenzene	ND	100		µg/L	100	10/21/2003
Chloroethane	ND	200		µg/L	100	10/21/2003
Chloroform	ND	100		µg/L	100	10/21/2003
Chloromethane	ND	100		µg/L	100	10/21/2003
2-Chlorotoluene	ND	100		µg/L	100	10/21/2003
4-Chlorotoluene	ND	100		µg/L	100	10/21/2003
cis-1,2-DCE	ND	100		µg/L	100	10/21/2003
cis-1,3-Dichloropropene	ND	100		µg/L	100	10/21/2003
1,2-Dibromo-3-chloropropane	ND	200		µg/L	100	10/21/2003
Dibromochloromethane	ND	100		µg/L	100	10/21/2003
Dibromomethane	ND	200		µg/L	100	10/21/2003
1,2-Dichlorobenzene	ND	100		µg/L	100	10/21/2003
1,3-Dichlorobenzene	ND	100		µg/L	100	10/21/2003
1,4-Dichlorobenzene	ND	100		µg/L	100	10/21/2003
Dichlorodifluoromethane	ND	100		µg/L	100	10/21/2003
1,1-Dichloroethane	ND	100		µg/L	100	10/21/2003
1,1-Dichloroethene	ND	100		µg/L	100	10/21/2003
1,2-Dichloropropane	ND	100		µg/L	100	10/21/2003
1,3-Dichloropropane	ND	100		µg/L	100	10/21/2003
2,2-Dichloropropane	ND	100		µg/L	100	10/21/2003

Qualifiers:

ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
B - Analyte detected in the associated Method Blank
* - Value exceeds Maximum Contaminant Level
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Pit
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:00:00 PM
Lab ID:	0310142-02A	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
1,1-Dichloropropene	ND	100		µg/L	100	10/21/2003
Hexachlorobutadiene	ND	100		µg/L	100	10/21/2003
2-Hexanone	ND	1000		µg/L	100	10/21/2003
Isopropylbenzene	ND	100		µg/L	100	10/21/2003
4-Isopropyltoluene	ND	100		µg/L	100	10/21/2003
4-Methyl-2-pentanone	ND	1000		µg/L	100	10/21/2003
Methylene Chloride	ND	300		µg/L	100	10/21/2003
n-Butylbenzene	ND	100		µg/L	100	10/21/2003
n-Propylbenzene	ND	100		µg/L	100	10/21/2003
sec-Butylbenzene	ND	100		µg/L	100	10/21/2003
Styrene	ND	100		µg/L	100	10/21/2003
tert-Butylbenzene	ND	100		µg/L	100	10/21/2003
1,1,1,2-Tetrachloroethane	ND	100		µg/L	100	10/21/2003
1,1,2,2-Tetrachloroethane	ND	100		µg/L	100	10/21/2003
Tetrachloroethene (PCE)	ND	100		µg/L	100	10/21/2003
trans-1,2-DCE	ND	100		µg/L	100	10/21/2003
trans-1,3-Dichloropropene	ND	100		µg/L	100	10/21/2003
1,2,3-Trichlorobenzene	ND	100		µg/L	100	10/21/2003
1,2,4-Trichlorobenzene	ND	100		µg/L	100	10/21/2003
1,1,1-Trichloroethane	ND	100		µg/L	100	10/21/2003
1,1,2-Trichloroethane	ND	100		µg/L	100	10/21/2003
Trichloroethene (TCE)	ND	100		µg/L	100	10/21/2003
Trichlorofluoromethane	ND	100		µg/L	100	10/21/2003
1,2,3-Trichloropropane	ND	200		µg/L	100	10/21/2003
Vinyl chloride	ND	200		µg/L	100	10/21/2003
Xylenes, Total	ND	100		µg/L	100	10/21/2003
Surr: 1,2-Dichloroethane-d4	93.6	70.6-124		%REC	100	10/21/2003
Surr: 4-Bromofluorobenzene	96.9	76.2-122		%REC	100	10/21/2003
Surr: Dibromofluoromethane	95.1	67.2-131		%REC	100	10/21/2003
Surr: Toluene-d8	108	82.1-123		%REC	100	10/21/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Pit
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:00:00 PM
Lab ID:	0310142-02B	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 8082: PCB'S						Analyst: **GT**
Aroclor 1016	ND	10		µg/L	1	11/4/2003 1:34:05 AM
Aroclor 1221	ND	50		µg/L	1	11/4/2003 1:34:05 AM
Aroclor 1232	ND	10		µg/L	1	11/4/2003 1:34:05 AM
Aroclor 1242	ND	10		µg/L	1	11/4/2003 1:34:05 AM
Aroclor 1248	ND	10		µg/L	1	11/4/2003 1:34:05 AM
Aroclor 1254	ND	10		µg/L	1	11/4/2003 1:34:05 AM
Aroclor 1260	ND	10		µg/L	1	11/4/2003 1:34:05 AM
Surr: Decachlorobiphenyl	43.0	76-111	S	%REC	1	11/4/2003 1:34:05 AM
Surr: Tetrachloro-m-xylene	42.0	47-94	S	%REC	1	11/4/2003 1:34:05 AM
EPA METHOD 8270D: SEMIVOLATILES						Analyst: **CS**
Acenaphthene	ND	100		µg/L	1	11/4/2003
Acenaphthylene	ND	100		µg/L	1	11/4/2003
Aniline	ND	100		µg/L	1	11/4/2003
Anthracene	ND	100		µg/L	1	11/4/2003
Azobenzene	ND	100		µg/L	1	11/4/2003
Benz(a)anthracene	ND	100		µg/L	1	11/4/2003
Benzidine	ND	200		µg/L	1	11/4/2003
Benzo(a)pyrene	ND	100		µg/L	1	11/4/2003
Benzo(b)fluoranthene	ND	100		µg/L	1	11/4/2003
Benzo(g,h,i)perylene	ND	100		µg/L	1	11/4/2003
Benzo(k)fluoranthene	ND	100		µg/L	1	11/4/2003
Benzoic acid	ND	500		µg/L	1	11/4/2003
Benzyl alcohol	ND	200		µg/L	1	11/4/2003
Bis(2-chloroethoxy)methane	ND	100		µg/L	1	11/4/2003
Bis(2-chloroethyl)ether	ND	100		µg/L	1	11/4/2003
Bis(2-chloroisopropyl)ether	ND	100		µg/L	1	11/4/2003
Bis(2-ethylhexyl)phthalate	160	100		µg/L	1	11/4/2003
4-Bromophenyl phenyl ether	ND	100		µg/L	1	11/4/2003
Butyl benzyl phthalate	ND	100		µg/L	1	11/4/2003
Carbazole	ND	100		µg/L	1	11/4/2003
4-Chloro-3-methylphenol	ND	200		µg/L	1	11/4/2003
4-Chloroaniline	ND	200		µg/L	1	11/4/2003
2-Chloronaphthalene	ND	100		µg/L	1	11/4/2003
2-Chlorophenol	ND	100		µg/L	1	11/4/2003
4-Chlorophenyl phenyl ether	ND	100		µg/L	1	11/4/2003
Chrysene	ND	100		µg/L	1	11/4/2003
Di-n-butyl phthalate	ND	100		µg/L	1	11/4/2003
Di-n-octyl phthalate	ND	100		µg/L	1	11/4/2003
Dibenz(a,h)anthracene	ND	100		µg/L	1	11/4/2003
Dibenzofuran	ND	100		µg/L	1	11/4/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Pit
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:00:00 PM
Lab ID:	0310142-02B	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
1,2-Dichlorobenzene	ND	100		µg/L	1	11/4/2003
1,3-Dichlorobenzene	ND	100		µg/L	1	11/4/2003
1,4-Dichlorobenzene	ND	100		µg/L	1	11/4/2003
3,3´-Dichlorobenzidine	ND	100		µg/L	1	11/4/2003
Diethyl phthalate	ND	100		µg/L	1	11/4/2003
Dimethyl phthalate	ND	100		µg/L	1	11/4/2003
2,4-Dichlorophenol	ND	100		µg/L	1	11/4/2003
2,4-Dimethylphenol	ND	100		µg/L	1	11/4/2003
4,6-Dinitro-2-methylphenol	ND	500		µg/L	1	11/4/2003
2,4-Dinitrophenol	ND	500		µg/L	1	11/4/2003
2,4-Dinitrotoluene	ND	100		µg/L	1	11/4/2003
2,6-Dinitrotoluene	ND	100		µg/L	1	11/4/2003
Fluoranthene	ND	100		µg/L	1	11/4/2003
Fluorene	ND	100		µg/L	1	11/4/2003
Hexachlorobenzene	ND	100		µg/L	1	11/4/2003
Hexachlorobutadiene	ND	100		µg/L	1	11/4/2003
Hexachlorocyclopentadiene	ND	100		µg/L	1	11/4/2003
Hexachloroethane	ND	100		µg/L	1	11/4/2003
Indeno(1,2,3-cd)pyrene	ND	100		µg/L	1	11/4/2003
Isophorone	ND	100		µg/L	1	11/4/2003
2-Methylnaphthalene	ND	100		µg/L	1	11/4/2003
2-Methylphenol	ND	100		µg/L	1	11/4/2003
3+4-Methylphenol	ND	100		µg/L	1	11/4/2003
N-Nitrosodi-n-propylamine	ND	100		µg/L	1	11/4/2003
N-Nitrosodiphenylamine	ND	100		µg/L	1	11/4/2003
Naphthalene	ND	100		µg/L	1	11/4/2003
2-Nitroaniline	ND	500		µg/L	1	11/4/2003
3-Nitroaniline	ND	500		µg/L	1	11/4/2003
4-Nitroaniline	ND	200		µg/L	1	11/4/2003
Nitrobenzene	ND	100		µg/L	1	11/4/2003
2-Nitrophenol	ND	100		µg/L	1	11/4/2003
4-Nitrophenol	ND	500		µg/L	1	11/4/2003
Pentachlorophenol	ND	500		µg/L	1	11/4/2003
Phenanthrene	ND	100		µg/L	1	11/4/2003
Phenol	ND	100		µg/L	1	11/4/2003
Pyrene	ND	100		µg/L	1	11/4/2003
Pyridine	ND	100		µg/L	1	11/4/2003
1,2,4-Trichlorobenzene	ND	100		µg/L	1	11/4/2003
2,4,5-Trichlorophenol	ND	100		µg/L	1	11/4/2003
2,4,6-Trichlorophenol	ND	100		µg/L	1	11/4/2003
Surr: 2,4,6-Tribromophenol	10.7	16.6-115	S	%REC	1	11/4/2003
Surr: 2-Fluorobiphenyl	79.9	37-95.7		%REC	1	11/4/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

J - Analyte detected below quantitation limits

B - Analyte detected in the associated Method Blank

* - Value exceeds Maximum Contaminant Level

S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Pit
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:00:00 PM
Lab ID:	0310142-02B	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
Surr: 2-Fluorophenol	5.41	9.54-89.8	S	%REC	1	11/4/2003
Surr: 4-Terphenyl-d14	62.1	47.9-115		%REC	1	11/4/2003
Surr: Nitrobenzene-d5	67.9	38-106		%REC	1	11/4/2003
Surr: Phenol-d6	18.5	10.7-63.4		%REC	1	11/4/2003

Qualifiers:

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- B - Analyte detected in the associated Method Blank
- * - Value exceeds Maximum Contaminant Level
- S - Spike Recovery outside accepted recovery limits
- R - RPD outside accepted recovery limits
- E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	R-4 Pit
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	10/20/2003 3:00:00 PM
Lab ID:	0310142-02C	**Matrix:**	AQUEOUS

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 300.0: ANIONS						Analyst: BL
Fluoride	ND	1.0		mg/L	10	10/21/2003 11:02:12 AM
Chloride	10	1.0		mg/L	10	10/21/2003 11:02:12 AM
Nitrogen, Nitrite (As N)	ND	1.0		mg/L	10	10/21/2003 11:02:12 AM
Nitrogen, Nitrate (As N)	ND	1.0		mg/L	10	10/21/2003 11:02:12 AM
Phosphorus, Orthophosphate (As P)	ND	5.0		mg/L	10	10/21/2003 11:02:12 AM
Sulfate	180	5.0		mg/L	10	10/21/2003 11:02:12 AM

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S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	Trip Blank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	
Lab ID:	0310142-03A	**Matrix:**	TRIP BLANK

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
EPA METHOD 8260B: VOLATILES						Analyst: **JDC**
Benzene	ND	1.0		µg/L	1	10/21/2003
Toluene	ND	1.0		µg/L	1	10/21/2003
Ethylbenzene	ND	1.0		µg/L	1	10/21/2003
Methyl tert-butyl ether (MTBE)	ND	1.0		µg/L	1	10/21/2003
1,2,4-Trimethylbenzene	ND	1.0		µg/L	1	10/21/2003
1,3,5-Trimethylbenzene	ND	1.0		µg/L	1	10/21/2003
1,2-Dichloroethane (EDC)	ND	1.0		µg/L	1	10/21/2003
1,2-Dibromoethane (EDB)	ND	1.0		µg/L	1	10/21/2003
Naphthalene	ND	2.0		µg/L	1	10/21/2003
1-Methylnaphthalene	ND	4.0		µg/L	1	10/21/2003
2-Methylnaphthalene	ND	4.0		µg/L	1	10/21/2003
Acetone	ND	10		µg/L	1	10/21/2003
Bromobenzene	ND	1.0		µg/L	1	10/21/2003
Bromochloromethane	ND	1.0		µg/L	1	10/21/2003
Bromodichloromethane	ND	1.0		µg/L	1	10/21/2003
Bromoform	ND	1.0		µg/L	1	10/21/2003
Bromomethane	ND	2.0		µg/L	1	10/21/2003
2-Butanone	ND	10		µg/L	1	10/21/2003
Carbon disulfide	ND	10		µg/L	1	10/21/2003
Carbon Tetrachloride	ND	1.0		µg/L	1	10/21/2003
Chlorobenzene	ND	1.0		µg/L	1	10/21/2003
Chloroethane	ND	2.0		µg/L	1	10/21/2003
Chloroform	ND	1.0		µg/L	1	10/21/2003
Chloromethane	ND	1.0		µg/L	1	10/21/2003
2-Chlorotoluene	ND	1.0		µg/L	1	10/21/2003
4-Chlorotoluene	ND	1.0		µg/L	1	10/21/2003
cis-1,2-DCE	ND	1.0		µg/L	1	10/21/2003
cis-1,3-Dichloropropene	ND	1.0		µg/L	1	10/21/2003
1,2-Dibromo-3-chloropropane	ND	2.0		µg/L	1	10/21/2003
Dibromochloromethane	ND	1.0		µg/L	1	10/21/2003
Dibromomethane	ND	2.0		µg/L	1	10/21/2003
1,2-Dichlorobenzene	ND	1.0		µg/L	1	10/21/2003
1,3-Dichlorobenzene	ND	1.0		µg/L	1	10/21/2003
1,4-Dichlorobenzene	ND	1.0		µg/L	1	10/21/2003
Dichlorodifluoromethane	ND	1.0		µg/L	1	10/21/2003
1,1-Dichloroethane	ND	1.0		µg/L	1	10/21/2003
1,1-Dichloroethene	ND	1.0		µg/L	1	10/21/2003
1,2-Dichloropropane	ND	1.0		µg/L	1	10/21/2003
1,3-Dichloropropane	ND	1.0		µg/L	1	10/21/2003
2,2-Dichloropropane	ND	1.0		µg/L	1	10/21/2003

Qualifiers:

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S - Spike Recovery outside accepted recovery limits

R - RPD outside accepted recovery limits

E - Value above quantitation range

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT:	Kleinfelder	**Client Sample ID:**	Trip Blank
Lab Order:	0310142	**Tag Number:**	
Project:	R-4 Characterization Well	**Collection Date:**	
Lab ID:	0310142-03A	**Matrix:**	TRIP BLANK

Analyses	Result	Limit	Qual	Units	DF	Date Analyzed
1,1-Dichloropropene	ND	1.0		µg/L	1	10/21/2003
Hexachlorobutadiene	ND	1.0		µg/L	1	10/21/2003
2-Hexanone	ND	10		µg/L	1	10/21/2003
Isopropylbenzene	ND	1.0		µg/L	1	10/21/2003
4-Isopropyltoluene	ND	1.0		µg/L	1	10/21/2003
4-Methyl-2-pentanone	ND	10		µg/L	1	10/21/2003
Methylene Chloride	ND	3.0		µg/L	1	10/21/2003
n-Butylbenzene	ND	1.0		µg/L	1	10/21/2003
n-Propylbenzene	ND	1.0		µg/L	1	10/21/2003
sec-Butylbenzene	ND	1.0		µg/L	1	10/21/2003
Styrene	ND	1.0		µg/L	1	10/21/2003
tert-Butylbenzene	ND	1.0		µg/L	1	10/21/2003
1,1,1,2-Tetrachloroethane	ND	1.0		µg/L	1	10/21/2003
1,1,2,2-Tetrachloroethane	ND	1.0		µg/L	1	10/21/2003
Tetrachloroethene (PCE)	ND	1.0		µg/L	1	10/21/2003
trans-1,2-DCE	ND	1.0		µg/L	1	10/21/2003
trans-1,3-Dichloropropene	ND	1.0		µg/L	1	10/21/2003
1,2,3-Trichlorobenzene	ND	1.0		µg/L	1	10/21/2003
1,2,4-Trichlorobenzene	ND	1.0		µg/L	1	10/21/2003
1,1,1-Trichloroethane	ND	1.0		µg/L	1	10/21/2003
1,1,2-Trichloroethane	ND	1.0		µg/L	1	10/21/2003
Trichloroethene (TCE)	ND	1.0		µg/L	1	10/21/2003
Trichlorofluoromethane	ND	1.0		µg/L	1	10/21/2003
1,2,3-Trichloropropane	ND	2.0		µg/L	1	10/21/2003
Vinyl chloride	ND	2.0		µg/L	1	10/21/2003
Xylenes, Total	ND	1.0		µg/L	1	10/21/2003
Surr: 1,2-Dichloroethane-d4	92.9	70.6-124		%REC	1	10/21/2003
Surr: 4-Bromofluorobenzene	94.8	76.2-122		%REC	1	10/21/2003
Surr: Dibromofluoromethane	95.0	67.2-131		%REC	1	10/21/2003
Surr: Toluene-d8	104	82.1-123		%REC	1	10/21/2003

Qualifiers:

ND - Not Detected at the Reporting Limit

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R - RPD outside accepted recovery limits

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LABORATORY ANALYTICAL REPORT

Client: Hall Environmental
Project: R-4 Characterization Well
Lab ID: C03100848-001
Client Sample ID: R-4 Tank 0310142-01E

Report Date: 11/03/03
Collection Date: 10/20/03 15:30
Date Received: 10/22/03
Matrix: Aqueous

Analyses	Result	Units	Qual	RL	MCL/ QCL	Method	Analysis Date / By
MAJOR IONS							
Calcium	145	mg/L		1.0		E200.7	10/23/03 06:59 / cp
Magnesium	8.4	mg/L		1.0		E200.7	10/23/03 06:59 / cp
Potassium	6.6	mg/L		1.0		E200.7	10/23/03 06:59 / cp
Sodium	33.6	mg/L		1.0		E200.7	10/23/03 06:59 / cp
METALS - DISSOLVED							
Aluminum	0.056	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Antimony	ND	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Arsenic	0.003	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Barium	ND	mg/L		0.10		E200.7	10/23/03 06:59 / cp
Beryllium	ND	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Cadmium	ND	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Chromium	ND	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Cobalt	ND	mg/L		0.010		E200.7	10/23/03 06:59 / cp
Copper	0.038	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Iron	0.251	mg/L		0.030		E200.7	10/23/03 06:59 / cp
Lead	0.001	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Manganese	0.316	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Nickel	0.007	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Selenium	ND	mg/L	D	0.002		E200.8	10/24/03 00:51 / smd
Silver	ND	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Thallium	ND	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Vanadium	0.003	mg/L		0.001		E200.8	10/24/03 00:51 / smd
Zinc	0.074	mg/L		0.001		E200.8	10/24/03 00:51 / smd
METALS - TOTAL							
Mercury	ND	mg/L		0.0001		A3112 B	10/23/03 14:43 / sml
RADIONUCLIDES - TOTAL							
Gross Alpha	4.0	pCi/L		1.0		E900.0	10/24/03 09:00 / rs
Gross Alpha precision (±)	1.0	pCi/L				E900.0	10/24/03 09:00 / rs
Gross Gamma	ND	pCi/L		20.0		E901.1	10/28/03 17:25 / db
Tritium	ND	pCi/L		1200		E906.0	10/27/03 12:00 / db

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Hall Environmental
Project: R-4 Characterization Well
Lab ID: C03100848-002
Client Sample ID: R-4 Pit 0310142-02E

Report Date: 11/03/03
Collection Date: 10/20/03 15:00
Date Received: 10/22/03
Matrix: Aqueous

Analyses	Result	Units	Qual	RL	MCL/ QCL	Method	Analysis Date / By
MAJOR IONS							
Calcium	18.9	mg/L		1.0		E200.7	10/23/03 07:01 / cp
Magnesium	3.9	mg/L		1.0		E200.7	10/23/03 07:01 / cp
Potassium	8.1	mg/L		1.0		E200.7	10/23/03 07:01 / cp
Sodium	202	mg/L		1.0		E200.7	10/23/03 07:01 / cp
METALS - DISSOLVED							
Aluminum	6.92	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Antimony	0.005	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Arsenic	0.037	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Barium	ND	mg/L		0.10		E200.7	10/23/03 07:01 / cp
Beryllium	ND	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Cadmium	0.001	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Chromium	0.002	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Cobalt	ND	mg/L		0.010		E200.7	10/23/03 07:01 / cp
Copper	0.385	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Iron	0.106	mg/L		0.030		E200.7	10/23/03 07:01 / cp
Lead	0.008	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Manganese	0.140	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Nickel	0.015	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Selenium	ND	mg/L	D	0.002		E200.8	10/24/03 00:57 / smd
Silver	0.002	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Thallium	ND	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Vanadium	0.005	mg/L		0.001		E200.8	10/24/03 00:57 / smd
Zinc	0.057	mg/L		0.001		E200.8	10/24/03 00:57 / smd
METALS - TOTAL							
Mercury	ND	mg/L		0.0001		A3112 B	10/23/03 14:45 / sml
RADIONUCLIDES - TOTAL							
Gross Alpha	16.3	pCi/L		1.0		E900.0	10/24/03 09:00 / rs
Gross Alpha precision (±)	1.2	pCi/L				E900.0	10/24/03 09:00 / rs
Gross Gamma	ND	pCi/L		20.0		E901.1	10/28/03 17:25 / db
Tritium	ND	pCi/L		1200		E906.0	10/27/03 12:00 / db

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

QA/QC Summary Report

Client: Hall Environmental
Project: R-4 Characterization Well

Report Date: 11/03/03
Work Order: C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A3112 B									Batch: HG3112-7470-031023
Sample ID: MBLK	Method Blank								10/23/03 14:36
Mercury	ND	mg/L	0.00100						
Sample ID: C03100761-001B MS	Matrix Spike								10/23/03 14:47
Mercury	0.00436	mg/L	0.000100	107	85	115			
Sample ID: C03100761-001B MSD	Matrix Spike Duplicate								10/23/03 14:50
Mercury	0.00450	mg/L	0.000100	110	85	115	3.0	10	

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Hall Environmental
Project: R-4 Characterization Well

Report Date: 11/03/03
Work Order: C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Batch: R27764
Sample ID: LRB	Method Blank								10/23/03 12:30
Aluminum	ND	mg/L	0.00100						
Antimony	ND	mg/L	0.00100						
Arsenic	ND	mg/L	0.00100						
Beryllium	ND	mg/L	0.00100						
Cadmium	ND	mg/L	0.00100						
Chromium	ND	mg/L	0.00100						
Copper	ND	mg/L	0.00100						
Lead	0.0000300	mg/L	0.00100						
Manganese	ND	mg/L	0.00100						
Nickel	ND	mg/L	0.00100						
Selenium	ND	mg/L	0.00100						
Silver	ND	mg/L	0.00100						
Thallium	ND	mg/L	0.00100						
Vanadium	ND	mg/L	0.00100						
Zinc	0.000880	mg/L	0.00100						
Sample ID: C03100682-005AMS	Matrix Spike								10/23/03 15:35
Aluminum	0.767	mg/L	0.00100	77.5	70	130			
Antimony	0.518	mg/L	0.00100	103	70	130			
Arsenic	0.500	mg/L	0.00200	100	70	130			
Beryllium	0.430	mg/L	0.00100	85.9	70	130			
Cadmium	0.487	mg/L	0.00100	97.2	70	130			
Chromium	0.502	mg/L	0.00200	100	70	130			
Copper	0.483	mg/L	0.00100	94.5	70	130			
Lead	0.510	mg/L	0.00100	101	70	130			
Manganese	1.76	mg/L	0.00100	95.2	70	130			
Nickel	0.553	mg/L	0.00100	95	70	130			
Selenium	0.520	mg/L	0.00500	101	70	130			
Silver	0.195	mg/L	0.00100	97.6	70	130			
Thallium	0.511	mg/L	0.00100	102	70	130			
Vanadium	0.509	mg/L	0.00100	102	70	130			
Zinc	0.678	mg/L	0.00100	89.3	70	130			
Sample ID: C03100682-005AMSD	Matrix Spike Duplicate								10/23/03 15:40
Aluminum	0.764	mg/L	0.00100	76.9	70	130	0.4	20	
Antimony	0.540	mg/L	0.00100	108	70	130	4.3	20	
Arsenic	0.524	mg/L	0.00200	105	70	130	4.6	20	
Beryllium	0.432	mg/L	0.00100	86.4	70	130	0.6	20	
Cadmium	0.496	mg/L	0.00100	99	70	130	1.8	20	
Chromium	0.515	mg/L	0.00200	103	70	130	2.5	20	
Copper	0.501	mg/L	0.00100	98	70	130	3.6	20	
Lead	0.526	mg/L	0.00100	104	70	130	3.0	20	

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

QA/QC Summary Report

Client: Hall Environmental **Report Date:** 11/03/03
Project: R-4 Characterization Well **Work Order:** C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Batch: R27764
Sample ID: C03100682-005AMSD	Matrix Spike Duplicate								10/23/03 15:40
Manganese	1.77	mg/L	0.00100	98.8	70	130	1.0	20	
Nickel	0.573	mg/L	0.00100	98.9	70	130	3.5	20	
Selenium	0.547	mg/L	0.00500	107	70	130	5.1	20	
Silver	0.201	mg/L	0.00100	100	70	130	2.9	20	
Thallium	0.520	mg/L	0.00100	104	70	130	1.7	20	
Vanadium	0.519	mg/L	0.00100	104	70	130	1.8	20	
Zinc	0.702	mg/L	0.00100	94.1	70	130	3.5	20	
Sample ID: C03100697-008AMS	Matrix Spike								10/23/03 16:49
Aluminum	0.306	mg/L	0.00100	96.2	70	130			
Antimony	0.258	mg/L	0.00100	103	70	130			
Arsenic	0.255	mg/L	0.00100	101	70	130			
Beryllium	0.257	mg/L	0.00100	103	70	130			
Cadmium	0.243	mg/L	0.00100	97.1	70	130			
Chromium	0.250	mg/L	0.00100	100	70	130			
Copper	0.238	mg/L	0.00100	93.7	70	130			
Lead	0.247	mg/L	0.00100	98.4	70	130			
Manganese	0.256	mg/L	0.00100	99.6	70	130			
Nickel	0.241	mg/L	0.00100	94.8	70	130			
Selenium	0.294	mg/L	0.00250	101	70	130			
Silver	0.0955	mg/L	0.00100	95.5	70	130			
Thallium	0.247	mg/L	0.00100	98.9	70	130			
Vanadium	0.259	mg/L	0.00100	101	70	130			
Zinc	0.240	mg/L	0.00100	89.9	70	130			
Sample ID: C03100697-008AMSD	Matrix Spike Duplicate								10/23/03 16:54
Aluminum	0.290	mg/L	0.00100	89.8	70	130	5.4	20	
Antimony	0.255	mg/L	0.00100	102	70	130	1.2	20	
Arsenic	0.253	mg/L	0.00100	100	70	130	0.8	20	
Beryllium	0.255	mg/L	0.00100	102	70	130	0.8	20	
Cadmium	0.238	mg/L	0.00100	95.1	70	130	2.1	20	
Chromium	0.245	mg/L	0.00100	97.9	70	130	2.1	20	
Copper	0.236	mg/L	0.00100	93	70	130	0.8	20	
Lead	0.245	mg/L	0.00100	97.5	70	130	0.8	20	
Manganese	0.254	mg/L	0.00100	98.9	70	130	0.7	20	
Nickel	0.238	mg/L	0.00100	93.7	70	130	1.1	20	
Selenium	0.301	mg/L	0.00250	104	70	130	2.3	20	
Silver	0.0949	mg/L	0.00100	94.9	70	130	0.6	20	
Thallium	0.242	mg/L	0.00100	96.8	70	130	2.1	20	
Vanadium	0.254	mg/L	0.00100	98.9	70	130	1.7	20	
Zinc	0.239	mg/L	0.00100	89.7	70	130	0.1	20	

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Hall Environmental — **Report Date:** 11/03/03
Project: R-4 Characterization Well — **Work Order:** C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Batch: R27764
Sample ID: C03100789-002AMS	Matrix Spike								10/23/03 18:13
Antimony	0.248	mg/L	0.00100	99.2	70	130			
Arsenic	0.268	mg/L	0.00100	102	70	130			
Beryllium	0.268	mg/L	0.00100	107	70	130			
Cadmium	0.250	mg/L	0.00100	99.9	70	130			
Chromium	0.276	mg/L	0.00100	103	70	130			
Copper	0.252	mg/L	0.00100	96.1	70	130			
Lead	0.256	mg/L	0.00100	99	70	130			
Manganese	0.742	mg/L	0.00100	104	70	130			
Nickel	0.260	mg/L	0.00100	95.6	70	130			
Selenium	0.257	mg/L	0.00250	103	70	130			
Silver	0.0708	mg/L	0.00100	70.8	70	130			
Thallium	0.245	mg/L	0.00100	98.1	70	130			
Vanadium	0.271	mg/L	0.00100	102	70	130			
Zinc	0.281	mg/L	0.00100	97.9	70	130			
Sample ID: C03100789-002AMSD	Matrix Spike Duplicate								10/23/03 18:19
Antimony	0.248	mg/L	0.00100	99.3	70	130	0.1	20	
Arsenic	0.273	mg/L	0.00100	104	70	130	1.8	20	
Beryllium	0.268	mg/L	0.00100	107	70	130	0	20	
Cadmium	0.251	mg/L	0.00100	100	70	130	0.5	20	
Chromium	0.277	mg/L	0.00100	103	70	130	0.3	20	
Copper	0.253	mg/L	0.00100	96.7	70	130	0.6	20	
Lead	0.259	mg/L	0.00100	100	70	130	1.1	20	
Manganese	0.724	mg/L	0.00100	96.7	70	130	2.4	20	
Nickel	0.267	mg/L	0.00100	98.5	70	130	2.8	20	
Selenium	0.269	mg/L	0.00250	107	70	130	4.6	20	
Silver	0.0700	mg/L	0.00100	70	70	130	1.2	20	
Thallium	0.251	mg/L	0.00100	100	70	130	2.2	20	
Vanadium	0.270	mg/L	0.00100	101	70	130	0.4	20	
Zinc	0.279	mg/L	0.00100	96.8	70	130	1.0	20	
Sample ID: C03100478-011AMS	Matrix Spike								10/23/03 19:28
Aluminum	0.922	mg/L	0.00100	91.1	70	130			
Antimony	0.511	mg/L	0.00100	102	70	130			
Arsenic	0.522	mg/L	0.00200	104	70	130			
Beryllium	0.536	mg/L	0.00100	107	70	130			
Cadmium	0.492	mg/L	0.00100	98.5	70	130			
Chromium	0.527	mg/L	0.00200	105	70	130			
Copper	0.492	mg/L	0.00100	97.5	70	130			
Lead	0.509	mg/L	0.00100	99.8	70	130			
Manganese	0.528	mg/L	0.00100	105	70	130			
Nickel	0.499	mg/L	0.00100	97.8	70	130			

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

QA/QC Summary Report

Client: Hall Environmental
Project: R-4 Characterization Well

Report Date: 11/03/03
Work Order: C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Batch: R27764	
Sample ID: C03100478-011AMS	Matrix Spike							10/23/03 19:28	
Selenium	0.554	mg/L	0.00500	105	70	130			
Silver	0.197	mg/L	0.00100	98.4	70	130			
Thallium	0.502	mg/L	0.00100	100	70	130			
Vanadium	0.524	mg/L	0.00100	105	70	130			
Zinc	0.513	mg/L	0.00100	92.6	70	130			
Sample ID: C03100478-011AMSD	Matrix Spike Duplicate							10/23/03 19:33	
Aluminum	0.862	mg/L	0.00100	78.9	70	130	6.8	20	
Antimony	0.492	mg/L	0.00100	98.4	70	130	3.7	20	
Arsenic	0.495	mg/L	0.00200	98.6	70	130	5.2	20	
Beryllium	0.521	mg/L	0.00100	104	70	130	2.9	20	
Cadmium	0.477	mg/L	0.00100	95.3	70	130	3.3	20	
Chromium	0.506	mg/L	0.00200	101	70	130	4.0	20	
Copper	0.465	mg/L	0.00100	92.1	70	130	5.7	20	
Lead	0.487	mg/L	0.00100	95.3	70	130	4.5	20	
Manganese	0.507	mg/L	0.00100	100	70	130	4.0	20	
Nickel	0.483	mg/L	0.00100	94.7	70	130	3.2	20	
Selenium	0.520	mg/L	0.00500	98.5	70	130	6.3	20	
Silver	0.186	mg/L	0.00100	93	70	130	5.6	20	
Thallium	0.477	mg/L	0.00100	95.4	70	130	5.0	20	
Vanadium	0.509	mg/L	0.00100	102	70	130	2.9	20	
Zinc	0.503	mg/L	0.00100	90.6	70	130	2.0	20	
Sample ID: C03100478-022AMS	Matrix Spike							10/23/03 20:42	
Aluminum	0.925	mg/L	0.00100	101	70	130			
Antimony	0.532	mg/L	0.00100	106	70	130			
Arsenic	0.507	mg/L	0.00200	100	70	130			
Beryllium	0.566	mg/L	0.00100	113	70	130			
Cadmium	0.502	mg/L	0.00100	100	70	130			
Chromium	0.520	mg/L	0.00200	104	70	130			
Copper	0.487	mg/L	0.00100	95.9	70	130			
Lead	0.522	mg/L	0.00100	104	70	130			
Manganese	0.793	mg/L	0.00100	107	70	130			
Nickel	0.513	mg/L	0.00100	99.8	70	130			
Selenium	0.504	mg/L	0.00500	101	70	130			
Silver	0.198	mg/L	0.00100	99	70	130			
Thallium	0.511	mg/L	0.00100	102	70	130			
Vanadium	0.531	mg/L	0.00100	106	70	130			
Zinc	0.505	mg/L	0.00100	92.1	70	130			
Sample ID: C03100478-022AMSD	Matrix Spike Duplicate							10/23/03 20:47	
Aluminum	0.863	mg/L	0.00100	88.5	70	130	6.9	20	

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Hall Environmental **Report Date:** 11/03/03
Project: R-4 Characterization Well **Work Order:** C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Batch: R27764
Sample ID: C03100478-022AMSD	Matrix Spike Duplicate								10/23/03 20:47
Antimony	0.510	mg/L	0.00100	102	70	130	4.2	20	
Arsenic	0.505	mg/L	0.00200	99.9	70	130	0.4	20	
Beryllium	0.540	mg/L	0.00100	108	70	130	4.7	20	
Cadmium	0.492	mg/L	0.00100	98.2	70	130	2.0	20	
Chromium	0.513	mg/L	0.00200	103	70	130	1.3	20	
Copper	0.482	mg/L	0.00100	95	70	130	0.9	20	
Lead	0.518	mg/L	0.00100	103	70	130	0.8	20	
Manganese	0.782	mg/L	0.00100	105	70	130	1.3	20	
Nickel	0.498	mg/L	0.00100	96.7	70	130	3.1	20	
Selenium	0.492	mg/L	0.00500	98.3	70	130	2.6	20	
Silver	0.193	mg/L	0.00100	96.4	70	130	2.8	20	
Thallium	0.506	mg/L	0.00100	101	70	130	0.8	20	
Vanadium	0.521	mg/L	0.00100	104	70	130	1.8	20	
Zinc	0.499	mg/L	0.00100	90.9	70	130	1.2	20	
Method: E900.0									Batch: R28107
Sample ID: C03100645-001A	Matrix Spike Duplicate								10/24/03 09:00
Gross Alpha	403	pCi/L	1.00	83	70	130	24	30	
Sample ID: MB-R28107	Method Blank								10/24/03 09:00
Gross Alpha	ND	pCi/L	1.00						
Sample ID: LCS-R28107	Laboratory Control Spike								10/24/03 09:00
Gross Alpha	465	pCi/L	1.00	95.7	70	130			
Method: E901.1									Batch: R28101
Sample ID: MB-R28101	Method Blank								10/28/03 17:25
Gross Gamma	ND	pCi/L	20.0						
Sample ID: LCS-R28101	Laboratory Control Spike								10/28/03 17:25
Gross Gamma	458000	pCi/L	20.0	95.9	70	130			
Sample ID: C03100848-001ADUP	Sample Duplicate								10/28/03 17:25
Gross Gamma	ND	pCi/L	20.0				0	30	

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

QA/QC Summary Report

Client: Hall Environmental
Project: R-4 Characterization Well

Report Date: 11/03/03
Work Order: C03100848

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E906.0									Batch: R27904
Sample ID: C03100941-001AMS	Matrix Spike								10/27/03 12:00
Tritium	2500	pCi/L	1200	108	70	130			
Sample ID: C03100941-001AMSD	Matrix Spike Duplicate								10/27/03 12:00
Tritium	2300	pCi/L	1200	100	70	130	7.4	30	
Sample ID: MB-R27904	Method Blank								10/27/03 12:00
Tritium	ND	pCi/L	1200						

Qualifiers: RL - Analyte reporting limit. ND - Not detected at the reporting limit.

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

Sample ID **MB 102103** Batch ID: **R9883** Test Code: **E300** Units: **mg/L** Analysis Date **10/21/2003 10:08:26 A** Prep Date

Client ID: Run ID: **LC_031021A** SeqNo: **221862**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Fluoride	0.02151	0.10									J
Chloride	ND	0.10									
Nitrogen, Nitrite (As N)	ND	0.10									
Nitrogen, Nitrate (As N)	ND	0.10									
Phosphorus, Orthophosphate (As P)	ND	0.50									
Sulfate	ND	0.50									

Sample ID **MB-4530** Batch ID: **4530** Test Code: **SW8080A** Units: **µg/L** Analysis Date **11/3/2003 10:29:17 PM** Prep Date **10/23/2003**

Client ID: Run ID: **ECD(17A)_031103A** SeqNo: **224349**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	ND	1.0									
Aroclor 1221	ND	5.0									
Aroclor 1232	ND	1.0									
Aroclor 1242	ND	1.0									
Aroclor 1248	ND	1.0									
Aroclor 1254	ND	1.0									
Aroclor 1260	ND	1.0									
Surr: Decachlorobiphenyl	4.03	0	5	0	80.6	76	111	0			
Surr: Tetrachloro-m-xylene	3.6	0	5	0	72.0	47	94	0			

Qualifiers: ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
B - Analyte detected in the associated Method Blank

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

Sample ID **MB-4525** Batch ID: **4525** Test Code: **SW8270A** Units: **µg/L** Analysis Date **11/3/2003** Prep Date **10/22/2003**

Client ID: Run ID: **ELMO_031103A** SeqNo: **224396**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Acenaphthene	ND	10									
Acenaphthylene	ND	10									
Aniline	ND	10									
Anthracene	ND	10									
Azobenzene	ND	10									
Benz(a)anthracene	ND	10									
Benzidine	ND	20									
Benzo(a)pyrene	ND	10									
Benzo(b)fluoranthene	ND	10									
Benzo(g,h,i)perylene	ND	10									
Benzo(k)fluoranthene	ND	10									
Benzoic acid	ND	50									
Benzyl alcohol	ND	20									
Bis(2-chloroethoxy)methane	ND	10									
Bis(2-chloroethyl)ether	ND	10									
Bis(2-chloroisopropyl)ether	ND	10									
Bis(2-ethylhexyl)phthalate	6.6	10									J
4-Bromophenyl phenyl ether	ND	10									
Butyl benzyl phthalate	ND	10									
Carbazole	ND	10									
4-Chloro-3-methylphenol	ND	20									
4-Chloroaniline	ND	20									
2-Chloronaphthalene	ND	10									
2-Chlorophenol	ND	10									
4-Chlorophenyl phenyl ether	ND	10									
Chrysene	ND	10									
Di-n-butyl phthalate	3.5	10									J
Di-n-octyl phthalate	6.9	10									J

Qualifiers: ND - Not Detected at the Reporting Limit; S - Spike Recovery outside accepted recovery limits; B - Analyte detected in the associated Method Blank

J - Analyte detected below quantitation limits; R - RPD outside accepted recovery limits

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

Dibenz(a,h)anthracene	ND	10
Dibenzofuran	ND	10
1,2-Dichlorobenzene	ND	10
1,3-Dichlorobenzene	ND	10
1,4-Dichlorobenzene	ND	10
3,3'-Dichlorobenzidine	ND	10
Diethyl phthalate	ND	10
Dimethyl phthalate	ND	10
2,4-Dichlorophenol	ND	10
2,4-Dimethylphenol	ND	10
4,6-Dinitro-2-methylphenol	ND	50
2,4-Dinitrophenol	ND	50
2,4-Dinitrotoluene	ND	10
2,6-Dinitrotoluene	ND	10
Fluoranthene	ND	10
Fluorene	ND	10
Hexachlorobenzene	ND	10
Hexachlorobutadiene	ND	10
Hexachlorocyclopentadiene	ND	10
Hexachloroethane	ND	10
Indeno(1,2,3-cd)pyrene	ND	10
Isophorone	ND	10
2-Methylnaphthalene	ND	10
2-Methylphenol	ND	10
3+4-Methylphenol	ND	10
N-Nitrosodi-n-propylamine	ND	10
N-Nitrosodiphenylamine	ND	10
Naphthalene	ND	10
2-Nitroaniline	ND	50
3-Nitroaniline	ND	50
4-Nitroaniline	ND	20
Nitrobenzene	ND	10
2-Nitrophenol	ND	10

Qualifiers: ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
B - Analyte detected in the associated Method Blank

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

4-Nitrophenol	ND	50						
Pentachlorophenol	ND	50						
Phenanthrene	ND	10						
Phenol	ND	10						
Pyrene	ND	10						
Pyridine	ND	10						
1,2,4-Trichlorobenzene	ND	10						
2,4,5-Trichlorophenol	ND	10						
2,4,6-Trichlorophenol	ND	10						
Surr: 2,4,6-Tribromophenol	109.6	0	200	0	54.8	16.6	115	0
Surr: 2-Fluorobiphenyl	69.3	0	100	0	69.3	37	95.7	0
Surr: 2-Fluorophenol	79.06	0	200	0	39.5	9.54	89.8	0
Surr: 4-Terphenyl-d14	91.35	0	100	0	91.4	70	130	0
Surr: Nitrobenzene-d5	64.56	0	100	0	64.6	38	106	0
Surr: Phenol-d6	81.92	0	200	0	41.0	10.7	63.4	0

Qualifiers:
ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
B - Analyte detected in the associated Method Blank

Hall Environmental Analysis Laboratory

Date: *05-Nov-03*

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

Sample ID **5ml rb** Batch ID: **R9880** Test Code: **SW8260B** Units: **µg/L** Analysis Date **10/21/2003** Prep Date

Client ID: Run ID: **NEPTUNE_031021A** SeqNo: **221817**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	ND	1.0									
Toluene	ND	1.0									
Ethylbenzene	ND	1.0									
Methyl tert-butyl ether (MTBE)	ND	1.0									
1,2,4-Trimethylbenzene	ND	1.0									
1,3,5-Trimethylbenzene	ND	1.0									
1,2-Dichloroethane (EDC)	ND	1.0									
1,2-Dibromoethane (EDB)	ND	1.0									
Naphthalene	ND	2.0									
1-Methylnaphthalene	ND	4.0									
2-Methylnaphthalene	ND	4.0									
Acetone	ND	10									
Bromobenzene	ND	1.0									
Bromochloromethane	ND	1.0									
Bromodichloromethane	ND	1.0									
Bromoform	ND	1.0									
Bromomethane	ND	2.0									
2-Butanone	ND	10									
Carbon disulfide	ND	10									
Carbon Tetrachloride	ND	1.0									
Chlorobenzene	ND	1.0									
Chloroethane	ND	2.0									
Chloroform	ND	1.0									
Chloromethane	ND	1.0									
2-Chlorotoluene	ND	1.0									
4-Chlorotoluene	ND	1.0									
cis-1,2-DCE	ND	1.0									

Qualifiers:
ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
B - Analyte detected in the associated Method Blank

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

cis-1,3-Dichloropropene	ND	1.0
1,2-Dibromo-3-chloropropane	ND	2.0
Dibromochloromethane	ND	1.0
Dibromomethane	ND	2.0
1,2-Dichlorobenzene	ND	1.0
1,3-Dichlorobenzene	ND	1.0
1,4-Dichlorobenzene	ND	1.0
Dichlorodifluoromethane	ND	1.0
1,1-Dichloroethane	ND	1.0
1,1-Dichloroethene	ND	1.0
1,2-Dichloropropane	ND	1.0
1,3-Dichloropropane	ND	1.0
2,2-Dichloropropane	ND	1.0
1,1-Dichloropropene	ND	1.0
Hexachlorobutadiene	ND	1.0
2-Hexanone	ND	10
Isopropylbenzene	ND	1.0
4-Isopropyltoluene	ND	1.0
4-Methyl-2-pentanone	ND	10
Methylene Chloride	ND	3.0
n-Butylbenzene	ND	1.0
n-Propylbenzene	ND	1.0
sec-Butylbenzene	ND	1.0
Styrene	ND	1.0
tert-Butylbenzene	ND	1.0
1,1,1,2-Tetrachloroethane	ND	1.0
1,1,2,2-Tetrachloroethane	ND	1.0
Tetrachloroethene (PCE)	ND	1.0
trans-1,2-DCE	ND	1.0
trans-1,3-Dichloropropene	ND	1.0
1,2,3-Trichlorobenzene	ND	1.0
1,2,4-Trichlorobenzene	ND	1.0
1,1,1-Trichloroethane	ND	1.0

Qualifiers: ND - Not Detected at the Reporting Limit; S - Spike Recovery outside accepted recovery limits; B - Analyte detected in the associated Method Blank; J - Analyte detected below quantitation limits; R - RPD outside accepted recovery limits

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Method Blank

1,1,2-Trichloroethane	ND	1.0						
Trichloroethene (TCE)	ND	1.0						
Trichlorofluoromethane	ND	1.0						
1,2,3-Trichloropropane	ND	2.0						
Vinyl chloride	ND	2.0						
Xylenes, Total	ND	1.0						
Surr: 1,2-Dichloroethane-d4	9.11	0	10	0	91.1	68.4	127	0
Surr: 4-Bromofluorobenzene	9.694	0	10	0	96.9	70.4	126	0
Surr: Dibromofluoromethane	9.3	0	10	0	93.0	70.2	126	0
Surr: Toluene-d8	10.64	0	10	0	106	73.5	129	0

Qualifiers: ND - Not Detected at the Reporting Limit; S - Spike Recovery outside accepted recovery limits; B - Analyte detected in the associated Method Blank

J - Analyte detected below quantitation limits; R - RPD outside accepted recovery limits

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Laboratory Control Spike - generic

Sample ID **LCS 102103** Batch ID: **R9883** Test Code: **E300** Units: **mg/L** Analysis Date **10/21/2003 10:25:10 A** Prep Date
Client ID: Run ID: **LC_031021A** SeqNo: **221863**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Fluoride	0.5439	0.10	0.5	0.02151	104	90	110	0			
Chloride	5.451	0.10	5	0	109	90	110	0			
Nitrogen, Nitrite (As N)	0.9931	0.10	1	0	99.3	90	110	0			
Nitrogen, Nitrate (As N)	2.658	0.10	2.5	0	106	90	110	0			
Phosphorus, Orthophosphate (As P)	5.17	0.50	5	0	103	90	110	0			
Sulfate	10.57	0.50	10	0	106	90	110	0			

Sample ID **LCS-4530** Batch ID: **4530** Test Code: **SW8080A** Units: **µg/L** Analysis Date **11/3/2003 11:15:28 PM** Prep Date **10/23/2003**
Client ID: Run ID: **ECD(17A)_031103A** SeqNo: **224350**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	3.528	1.0	5	0	70.6	27.4	132	0			
Aroclor 1260	4.042	1.0	5	0	80.8	52.1	148	0			

Sample ID **LCSD-4530** Batch ID: **4530** Test Code: **SW8080A** Units: **µg/L** Analysis Date **11/4/2003 12:01:35 AM** Prep Date **10/23/2003**
Client ID: Run ID: **ECD(17A)_031103A** SeqNo: **224351**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	3.814	1.0	5	0	76.3	27.4	132	3.528	7.79	45.7	
Aroclor 1260	4.458	1.0	5	0	89.2	52.1	148	4.042	9.79	30	

Qualifiers: ND - Not Detected at the Reporting Limit; S - Spike Recovery outside accepted recovery limits; B - Analyte detected in the associated Method Blank
J - Analyte detected below quantitation limits; R - RPD outside accepted recovery limits

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Laboratory Control Spike - generic

Sample ID **100ng lcs** Batch ID: **R9880** Test Code: **SW8260B** Units: **µg/L** Analysis Date **10/21/2003** Prep Date

Client ID: Run ID: **NEPTUNE_031021A** SeqNo: **221818**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	19.83	1.0	20	0	99.2	71.2	122	0			
Toluene	20.86	1.0	20	0	104	87.7	122	0			
Chlorobenzene	22.43	1.0	20	0	112	85.6	136	0			
1,1-Dichloroethene	20.83	1.0	20	0	104	70.7	117	0			
Trichloroethene (TCE)	19.85	1.0	20	0	99.2	76.9	130	0			

Sample ID **100NG LCSD** Batch ID: **R9880** Test Code: **SW8260B** Units: **µg/L** Analysis Date **10/21/2003** Prep Date

Client ID: Run ID: **NEPTUNE_031021A** SeqNo: **221819**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	19.81	1.0	20	0	99.0	78.7	122	19.83	0.121	11	
Toluene	21.44	1.0	20	0	107	76	128	20.86	2.75	12.2	
Chlorobenzene	22	1.0	20	0	110	85.6	136	22.43	1.95	12	
1,1-Dichloroethene	20.65	1.0	20	0	103	70.7	117	20.83	0.839	19.3	
Trichloroethene (TCE)	19.02	1.0	20	0	95.1	76.9	130	19.85	4.24	15.5	

Qualifiers:
ND - Not Detected at the Reporting Limit
S - Spike Recovery outside accepted recovery limits
B - Analyte detected in the associated Method Blank
J - Analyte detected below quantitation limits
R - RPD outside accepted recovery limits

CLIENT: Kleinfelder
Work Order: 0310142
Project: R-4 Characterization Well

QC SUMMARY REPORT

Laboratory Control Spike - generic

Sample ID **LCS-4525** Batch ID: **4525** Test Code: **SW8270A** Units: **µg/L** Analysis Date **11/3/2003** Prep Date **10/22/2003**

Client ID: Run ID: **ELMO_031103A** SeqNo: **224397**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Acenaphthene	69.98	10	100	0	70.0	43.1	89.9	0			
4-Chloro-3-methylphenol	143.7	20	200	0	71.9	44.1	93.2	0			
2-Chlorophenol	143.9	10	200	0	72.0	20.7	98	0			
1,4-Dichlorobenzene	59.14	10	100	0	59.1	24.1	90.7	0			
2,4-Dinitrotoluene	78.46	10	100	0	78.5	43.2	101	0			
N-Nitrosodi-n-propylamine	68.36	10	100	0	68.4	44.6	99.9	0			
4-Nitrophenol	77.64	50	200	0	38.8	11	57.5	0			
Pentachlorophenol	157.2	50	200	0	78.6	8.65	105	0			
Phenol	79.88	10	200	0	39.9	21.1	55.3	0			
Pyrene	88.8	10	100	0	88.8	35.7	111	0			
1,2,4-Trichlorobenzene	62.42	10	100	0	62.4	30.2	89.6	0			

Sample ID **LCSD-4525** Batch ID: **4525** Test Code: **SW8270A** Units: **µg/L** Analysis Date **11/3/2003** Prep Date **10/22/2003**

Client ID: Run ID: **ELMO_031103A** SeqNo: **224398**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Acenaphthene	71.56	10	100	0	71.6	43.1	89.9	69.98	2.23	30.5	
4-Chloro-3-methylphenol	152.7	20	200	0	76.4	44.1	93.2	143.7	6.06	28.6	
2-Chlorophenol	145.8	10	200	0	72.9	20.7	98	143.9	1.28	107	
1,4-Dichlorobenzene	60.76	10	100	0	60.8	24.1	90.7	59.14	2.70	62.1	
2,4-Dinitrotoluene	80.3	10	100	0	80.3	43.2	101	78.46	2.32	14.7	
N-Nitrosodi-n-propylamine	69.26	10	100	0	69.3	44.6	99.9	68.36	1.31	30.3	
4-Nitrophenol	77.18	50	200	0	38.6	11	57.5	77.64	0.594	36.3	
Pentachlorophenol	155.4	50	200	0	77.7	8.65	105	157.2	1.14	49	
Phenol	83.64	10	200	0	41.8	21.1	55.3	79.88	4.60	52.4	
Pyrene	86.5	10	100	0	86.5	35.7	111	88.8	2.62	16.3	
1,2,4-Trichlorobenzene	66.5	10	100	0	66.5	30.2	89.6	62.42	6.33	36.4	

Qualifiers: ND - Not Detected at the Reporting Limit; S - Spike Recovery outside accepted recovery limits; B - Analyte detected in the associated Method Blank; J - Analyte detected below quantitation limits; R - RPD outside accepted recovery limits

Hall Environmental Analysis Laboratory

Sample Receipt Checklist

Client Name KLEIN — Date and Time Received: 10/20/2003

Work Order Number 0310142 — Received by AMF

Checklist completed by Anne Thorne (Signature) 10/20/03 (Date)

Matrix — Carrier name Client drop-off

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐	
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑	Not Shipped ☐
Custody seals intact on sample bottles?	Yes ☐	No ☐	N/A ☑	
Chain of custody present?	Yes ☑	No ☐		
Chain of custody signed when relinquished and received?	Yes ☑	No ☐		
Chain of custody agrees with sample labels?	Yes ☑	No ☐		
Samples in proper container/bottle?	Yes ☑	No ☐		
Sample containers intact?	Yes ☑	No ☐		
Sufficient sample volume for indicated test?	Yes ☑	No ☐		
All samples received within holding time?	Yes ☑	No ☐		
Water - VOA vials have zero headspace?	No VOA vials submitted ☐	Yes ☑	No ☐	
Water - pH acceptable upon receipt?	Yes ☐	No ☐	N/A ☑	

Container/Temp Blank temperature? **10°** *4° C ± 2 Acceptable* If given sufficient time to cool.

COMMENTS:

Client contacted ____________ Date contacted: ____________ Person contacted ____________

Contacted by: ____________ Regarding ____________

Comments: ____________

Corrective Action ____________

CHAIN-OF-CUSTODY RECORD

Accreditation Applied:
NELAC ☐ USACE ☐
Other: ____________

HALL ENVIRONMENTAL ANALYSIS LABORATORY
4901 Hawkins NE, Suite D
Albuquerque, New Mexico 87109
Tel. 505.345.3975 Fax 505.345.4107
www.hallenvironmental.com

Client: KLEINFELDER, INC

Address: 8300 JEFFERSON NE
SUITE B
ALBUQUERQUE, NM 87113

Phone #: 344-7373
Fax #: 344-1711

Project Name: R-4 CHARACTERIZATION WELL
Project #: 33220/7.9
Project Manager: MARK EVERETT
Sampler: BERNARD BOCKISCH
Sample Temperature: 10°C

ANALYSIS REQUEST

Date	Time	Matrix	Sample I.D. No.	Number/Volume	Preservative $HgCl_2$	Preservative HNO_3	Preservative H_2SO_4	HEAL No.	BTEX + MTBE + TMB's (8021)	BTEX + MTBE + TPH (Gasoline Only)	TPH Method 8015B MOD (Gas/Diesel)	TPH (Method 418.1)	EDB (Method 504.1)	EDC (Method 8021)	8310 (PNA or PAH)	~~RCRA 8 Metals~~ DISSOLVED METALS	Cations (Na, K, Ca, Mg)	Anions (F, Cl, NO_3, NO_2, PO_4, SO_4)	~~8081 Pesticides~~ / PCB's (8082)	8260 (VOA)	8270 (Semi-VOA)	PERCHLORATE	(GAMMA E901.1) (GROSS ALPHA/RADIUM E900.0, E906.?)	MERCURY 7470	Air Bubbles or Headspace (Y or N)
10/20/03	1530	H_2O	R-4 TANK	2-1L AMBER				0310142-1											✓		✓				
10/20/03	1530	H_2O	R-4 TANK	2-1L POLY		✓		-1															✓		
10/20/03	1530	H_2O	R-4 TANK	2-500ML POLY		[illegible]		-1								✓		✓				✓			
10/20/03	1530	H_2O	R-4 TANK	1-125ML POLY			✓	-1																✓	
10/20/03	1530	H_2O	R-4 TANK	3-40ML VOAS	✓			-1								[illegible]				✓					
10/20/03	1500	H_2O	R-4 PIT	2-1L AMBER				-2											✓		✓				
10/20/03	1500	H_2O	R-4 PIT	2-1L POLY		✓		-2															✓		
10/20/03	1500	H_2O	R-4 PIT	2-500ML POLY				-2								✓		✓				✓			
10/20/03	1500	H_2O	R-4 PIT	3-40ML VOAS	✓			-2												✓					
10/20/03	1500	H_2O	R-4 PIT	1-125ML POLY			✓	-2																✓	
			Trip Blank					-3																	

Date: 10/20/03 Time: 15:56 Relinquished By: (Signature) [signature]
Remarks: [signature] 10/20/03 17:45

Date: 10/20/03 Time: 17:45 Relinquished By: (Signature) [signature]
Remarks:

Remarks: DISSOLVED METALS NEEDS TO BE FILTERED IN LAB - COULD NOT BE FILTERED IN FIELD. RUSH 10 DAY TAT

Hall Environmental Analysis Laboratory

DATE: *05-Nov-03*

INVOICE

Remit To:	Hall Environmental Analysis 4901 Hawkins NE, Suite D Albuquerque, New Mexico 87109-
Attn:	Accounts Receivable
TEL:	(505) 345-3975 FAX: (505) 345-4107

Invoice TO: Kleinfelder
8300 Jefferson, NE Suite B
Albuquerque, NM 87113
Attn: Mark Everett
Phone: (505) 344-7373

Work Order: 0310142
PO Number: 33220/7.9
Delivery Order
Project Name R-4 Characterization Well
Date Received 10/20/2003

Invoice No: 0310142

Invoice Date: 05-Nov-03
Payment Terms: Net 30 Days

Item	Remarks	Matrix	Qty	Unit Price	Mult	Quoted	Test Total
AQPREP LIQ-LIQ: PCB.		Aqueous	2	$0.00	1	$0.00	$0.00
AQPREP SEP FUNNEL: BNA		Aqueous	2	$0.00	1	$0.00	$0.00
EPA Method 300.0: Anions		Aqueous	2	$85.00	1	$85.00	$170.00
EPA Method 314.0: Perchlorate		Aqueous	2	$130.00	1	$130.00	$260.00
EPA Method 6020: Dissolved		Aqueous	2	$220.00	1	$220.00	$440.00
EPA Method 7470: Mercury		Aqueous	2	$20.00	1	$20.00	$40.00
EPA Method 8082: PCB's		Aqueous	2	$70.00	1	$70.00	$140.00
EPA Method 8260B: VOLATILES		Aqueous	2	$100.00	1	$100.00	$200.00
EPA Method 8260B: VOLATILES		Aqueous	1	$0.00	1	$0.00	$0.00
EPA Method 8270D: Semivolatiles		Aqueous	2	$240.00	1	$240.00	$480.00
Gamma Emitting Radionuclides			2	$142.50	1.5	$213.75	$427.50
Gross Alpha Activity		Aqueous	2	$90.00	1.5	$135.00	$270.00
Tritium		Aqueous	2	$120.00	1.5	$180.00	$360.00

Order TOTAL:	**$2,787.50**
Discount:	0.00%
Sales Tax:	0.00%
Misc Charges:	$24.00
Subtotal:	$2,811.50
Payment Received:	$0.00
INVOICE Total	**$2,811.50**

Misc Comments Field Filter Fee 2 @ $12.00 ea

All invoices are due and payable net 30 days from receipt.

Appendix F

Activities Planned for Well R-4 Compared with Work Performed

Appendix F
Activities Planned for Well R-4 Compared with Work Performed

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	Well R-4 SAP (LANL 2003)	Well R-4 Actual Work
Planned Depth	100 to 500 ft into the regional aquifer	820 ft TD of approximately 100 ft through regional water table. Regional water table expected at ~720 ft.	Regional water table at 736 ft. Total drill depth 843' ft bgs.
Drilling Method	Methods may include, but are not limited to HSA, air-rotary/Odex/Stratex, air-rotary/Barber rig, and mud-rotary drilling	Fluid-assisted, open-hole, air rotary drilling.	Fluid-assisted, open-hole, air rotary, air rotary casing hammer and mud rotary drilling.
Amount of Core	10% of the borehole	In Well R-4, the core target depth is 200 ft, with the goal of completely penetrating the uppermost intermediate perched groundwater zone. However, coring will continue if perched zone is not yet encountered or, if present, not fully penetrated but will not exceed 300 ft.	Total core depth 233 ft bgs.
Lithologic Log	Log to be prepared from core, cutting and drilling performance	Log to be prepared from core, cuttings, geophysical logs and drilling performance.	Same as SAP
Number of Water Samples Collected for Contaminant Analysis	A water sample may be collected from each saturated zone, five zones assumed. The number of sampling events after well completion is not specified.	If perched water is encountered within the unsaturated zone, one groundwater sample will be collected within up to three perched zones. Groundwater samples will be collected within the regional aquifer at the regional water table and at the borehole TD, if feasible.	Two water samples were obtained, one from the perched zone of 110-125 ft bgs and one from the regional aquifer at 835 ft bgs.
Water Sample Analysis	Initial sampling: radiochemistry I, II, and III, ^3H, general inorganics, stable isotopes, VOCs, and metals. Saturated zones: radionuclides (tritium, strontium-90, cesium-137, americium-241, plutonium isotopes, uranium isotopes, gamma spectrometry, and gross alpha, gross beta, and gross gamma), stable isotopes (hydrogen, oxygen, and in special cases nitrogen), major ions (cations and anions), trace metals, and trace elements.	Groundwater will be analyzed for perchlorate, low-detection tritium, gamma spectroscopy, americium-241; plutonium-239, 240, strontium-90; technetium-99; uranium-234; uranium-235; uranium-238; bromide, chloride, fluoride, nitrate, nitrite, oxalate, phosphate, sulfate, uranium, target analyte list metals, and stable isotopes of hydrogen, oxygen, and nitrogen.	Same as SAP
Water Sample Field Measurements	Alkalinity, pH, specific conductance, temperature, turbidity	Carbonate alkalinity, pH, specific conductance, temperature, turbidity.	pH, specific conductance, temperature, turbidity.
Number of Core/Cuttings Samples Collected for Contaminant Analysis	Twenty samples of core or cuttings to be analyzed for potential contaminant identification in each borehole.	A minimum of two samples will be collected from each saturated zone encountered during drilling, if possible.	Eleven core or cuttings samples submitted for contaminant analysis.
Cuttings/Core Sample Analytes	Uppermost sample to be analyzed for a full range of compounds: deeper samples will be analyzed for the presence of radiochemistry I, II, and III	Bromine, chlorine, fluorine, iodine, nitrate, nitrite oxalate, phosphate, sulfate, perchlorate, arsenic, aluminum, calcium, iron, magnesium, manganese, sodium, potassium, stable	Same as SAP

Appendix F
Activities Planned for Well R-4 Compared with Work Performed

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	Well R-4 SAP (LANL 2003)	Well R-4 Actual Work
	analytes, tritium (low and high detection levels), and metals. Four samples to be analyzed for VOCs.	isotopes of hydrogen, oxygen, and nitrogen, tritium, americium-241, plutonium -238, plutonium-239, 240, strontium-90, technetium-99, uranium-234, uranium-235; uranium-238, gamma spectroscopy.	
Laboratory Hydraulic-Property Tests	Physical properties analyses will be conducted on 5 core samples and will typically include: moisture content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics.	No laboratory hydraulic property tests specified in plan.	No samples submitted.
Geology	Ten samples of core or cuttings will be collected for petrographic, X-ray fluorescence (XRF) and X-ray diffraction (XRD) analyses	The geology task leader will determine the number of samples for characterization of mineralogy, petrography, and geochemistry based on geologic and hydrogeologic conditions encountered during drilling.	Up to 7 samples are in curation awaiting characterization.
Geophysics	In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptibility, borehole color videotape (axial and sidescan), fluid temperature (saturated), single-point resistivity (saturated), and spontaneous potential (saturated). In general, cased-hole geophysics includes: gamma-gamma density, natural gamma, and thermal neutron.	Typical wireline logging service as planned: open-hole geophysics includes array induction imager, triple lithodensity, combinable magnetic resonance tool, natural gamma, natural gamma ray spectrometry, epithermal compensated neutron log, caliper, full-bore formation microimager, elemental capture spectrometer and borehole video. In general, cased-hole geophysics includes triple lithodensity, natural gamma, natural gamma ray spectrometry, epithermal compensated neutron log and elemental capture spectrometer.	Compensated Neutron Tool: 7 – 846 ft bgs Triple Litho-Density: 7 – 846 ft bgs Array Induction Tool: 10.5 – 840 ft bgs Elemental Capture Spectroscopy: 35 – 846 ft bgs Natural Gamma Spectroscopy: 10.5 – 826 ft bgs Combinable Magnetic Resonance: 35 – 846 ft bgs Full-bore Formation Micro Imager: 97 – 840 ft bgs.
Water-Level Measurements	Procedures and methods not specified in "Hydrogeologic Workplan"	Water levels will be determined for each saturated zone by water-level meter or by pressure transducer.	Water level meter (sounder) used to measure the regional water table.
Field Hydraulic-Property Tests	Not specified in hydrogeologic work plan	Slug or pumping tests may be conducted in saturated intervals once the well is completed.	Aquifer test conducted December 16, 2003 – December 23, 2003.
Shallow Piezometers	Not specified in hydrogeologic work plan	Not specified in SAP	Two piezometers were installed in the corehole. Bottom of screens at TDs of 125 ft and 231 ft bgs.
Surface Casing	Approximately 20-in outer diameter (O.D.) extends from land surface to 10-ft depth in underlying competent layer and grouted in place.	18-in OD schedule 40, low carbon steel casing will be installed as deep as possible below ground level (nominally 35-40 ft bgs) and will extend approximately 3 ft above the ground surface and cemented into place.	13 ⅜-in OD steel casing set at 40 ft bgs and cemented in-place.

Appendix F
Activities Planned for Well R-4 Compared with Work Performed

Activity	"Hydrogeologic Workplan" (LANL 1998, 59599)	Well R-4 SAP (LANL 2003)	Well R-4 Actual Work
Minimum Well Casing Size	6.625-in O.D.	5-in O.D. x 4.5-in inner diameter (ID)	5-in OD (4.46-in ID) stainless steel casing with external couplings.
Well Screen	Machine-slotted (0.01-in) stainless-steel screens with flush-jointed threads; number and length of screens to be determined on a site-specific basis and proposed to NMED	Well screen shall be constructed with multiple sections of 5.56-in O.D. pipe based stainless-steel screen, with a 0.02-in slot size.	5.27-in OD, rod-based stainless-steel screen with a 0.020-in slot size.
Sump	Stainless-steel casing with an end cap	5-in-diameter stainless steel casing, 30 ft long.	5-in OD stainless-steel casing, 24 ft long.
Backfill	Uncontaminated drill cuttings below sump and bentonite above sump	A bentonite chip and sand mix will be used to fill the annulus to within 75 ft of ground surface. The mix will be hydrated in place every 100 ft. Cement with 2% bentonite will be used to fill the remaining annulus.	A 75:25 mix of 10/20 sand and bentonite chips placed from TD to 10 ft below bottom of screen. Hydrated in 50 ft lifts.
Filter Material	>90% silica sand, properly sized for the 0.010-in slot size of the well screen; extends 2 ft above and below the well screen	A bentonite seal will be placed below each screened interval and allowed to hydrate for 1 hour to prevent mixing. A two-foot interval of fine grained (30/70) transition sand will be placed above and below each primary filter pack. The primary filter pack (20/40 sand) will extend from 5 ft below each screened interval to 5 ft above.	Primary filter pack constructed of 10/20 silica sand placed 10 ft below and 12.9 ft above the screen. Secondary filter pack constructed of 20/40 silica sand placed to 2-ft above primary filter pack.
Transition Seal	N/A*	N/A	A 50:50 mix of 10/20 sand and bentonite chips placed to 48 ft above secondary filter pack.
Bentonite Seal	N/A	N/A	A 10:1 mix of bentonite chips and 10/20 silica sand placed from the transition seal to 77 ft bgs.
Concrete Backfill	N/A	N/A	2,500 psi concrete with 4% bentonite placed from 77 ft bgs to near surface.

* N/A – Not specified in the two referenced documents.